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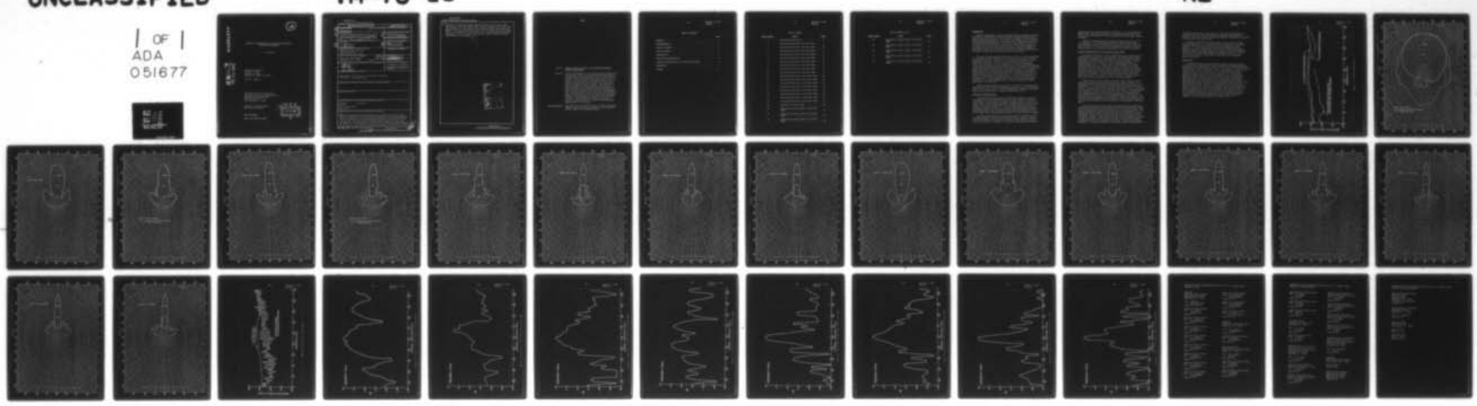

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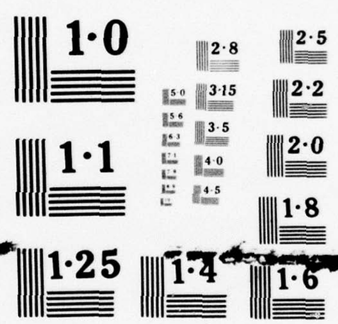

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ACOUSTIC CHARACTERISTICS OF THE ARL/FEU ELLIPSOIDAL
REFLECTING HYDROPHONE

G. C. Lauchle

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February 3, 1976
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Acoustic measurements in the Applied Research Laboratory's 48-inch water tunnel are often-times performed using an ellipsoidal reflecting hydrophone which is submerged in a water-filled tank located on the east side of the test section. Acoustic energy originating within the test section then propagates to the receiver via the acoustically transparent viewing windows. The reflector of this hydrophone system was originally fabricated by welding

over

20\. together two ellipsoidal-shaped spinnings along their perimeter while maintaining an air void between them. Recent indications were that leaks had developed, thus destroying the air void and, hence, the reflecting medium. The concave surface was then lined with highly reflective bubble rubber as a substitute for the true air void. This memorandum describes the changes in acoustic characteristics as a result of this and other modifications to the system.

Subject: Acoustic Characteristics of the ARL/FEU Ellipsoidal Reflecting Hydrophone

Abstract: Acoustic measurements in the Applied Research Laboratory's 48-inch water tunnel are often-times performed using an ellipsoidal reflecting hydrophone which is submerged in a water-filled tank located on the east side of the test section. Acoustic energy originating within the test section then propagates to the receiver via the acoustically transparent viewing windows. The reflector of this hydrophone system was originally fabricated by welding together two ellipsoidal-shaped spinnings along their perimeter while maintaining an air void between them. Recent indications were that leaks had developed, thus destroying the air void and, hence, the reflecting medium. The concave surface was then lined with highly reflective bubble rubber as a substitute for the true air void. This memorandum describes the changes in acoustic characteristics as a result of this and other modifications to the system.

Acknowledgements: This effort was supported by the U. S. Naval Sea Systems Command, Code 035. Also acknowledged is the assistance of W. L. Nuss in the electronic setup.

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INTRODUCTION

Acoustic measurements of flow generated noise in the Applied Research Laboratory's 48-inch water tunnel are usually performed using an ellipsoidal reflecting hydrophone. This device is composed of two ellipsoidal-shaped spinnings separated by an air void, where located at the focus is an omnidirectional hydrophone. The reflector and hydrophone are secured to a traversing mechanism which is part of a water-filled tank that is attached to the east side of the test section. The viewing windows are of plexiglass that has a characteristic acoustic impedance compatible with that of water and thus serves as the acoustic coupling medium between the water in the tunnel and the water in the external tank.

For each research program in which the system is used, the hydrophone is recalibrated with a sound projector placed at some critical location within the tunnel test section, i.e., this location is dictated by the experimental geometry. During a recent in-tunnel calibration, the sensitivity was found to be less than those of previous measurements. It was soon determined that the reflector part of the system had developed a leak and hence destroyed the air void (which is the medium of reflection). Under the assumption that repairing the leak would only be a temporary remedy (because the spinnings have undergone corrosive degradation), it was decided to line the concave surface with a permanent layer (1/8-inch thick) of highly reflective bubble rubber. It was further decided to replace the home-built ARL hydrophone probe (located at the focus) with a Celesco Corp. LC-10 hydrophone probe; and to line the external tank with Saper T, a sound absorbing rubber, to reduce secondary standing waves due to the tank walls.

This memorandum presents the results of sensitivity and directivity measurements of the reflecting hydrophone performed in (1) the free field, and in (2) the water tunnel. Wherever appropriate, comparisons are made between the characteristics of the new system and the old.

FREE-FIELD CHARACTERISTICS

The reflecting hydrophone was free-field calibrated in an anechoic tank located in the Ocean Technology Unit of ARL. Figure 1 shows the free-field, on-axis sensitivity (output voltage/pressure in) in the 5 to 50 kHz range. The well-known comparison method was used to measure these curves. The dash-dot broken line curve was measured in 1971 when the reflector was first fabricated. It is seen that approximately an 8 dB increase in sensitivity has been realized through coating the reflector with bubble rubber. We also note that the reflector equipped with the LC-10, commerically-made hydrophone exhibits a flatter frequency response.

The free-field directivity curves were measured for both the LC-10 and ARL hydrophones located at the reflector focus. Figures 2 through 10 show the directivity characteristics with the ARL probe at various discrete frequencies. Figures 2, 4, and 6 also show those directivities

measured with the uncoated reflector (1971 data). It is seen that the bubble rubber coating has resulted in a slight lowering of side lobe levels, while the beam width (3 dB down points) has essentially remained unchanged.

Figures 11 through 18 show the free-field directivity curves for the LC-10 probe. In comparing beam widths of these curves to the corresponding curves for the ARL probe, very little, if any, difference can be observed. On the basis of the sensitivity, however, the LC-10 probe appears to be the superior hydrophone to use with the reflector.

ACOUSTIC CHARACTERISTICS IN THE 48-INCH WATER TUNNEL

To assess the effects of tunnel reverberation, the measurements of sensitivity and directivity were repeated in the 48-inch water tunnel. The reflecting hydrophone was equipped with the LC-10 probe for these measurements. The external water tank was lined with Saper T sound absorbing rubber in an attempt to reduce standing waves that are assumed present there. A Celesco Corp. LC-32 hydrophone was placed at the geometrical center of the test section to serve as the sound projector. With the receiver directed toward the projector (on-axis), the projector was driven with a swept sinusoidal input voltage through the 5 to 50 kHz range. The received voltage was recorded on a level recorder and corrected for source output and distance to obtain the sensitivity curve. The result of this measurement is shown in Fig. 19 where the free-field sensitivity of Fig. 1 is also presented.

The mean line of the in-tunnel sensitivity curve falls 6 to 10 dB above those previously measured (before bubble rubber treatment) for frequencies above 20 kHz and has remained essentially the same for lower frequencies. It is disturbing that the free-field curve does not fall closer to the mean line of that measured in the tunnel, but it is believed that the reverberant field has caused this discrepancy. The maximum mean line difference, however, does not exceed 7 dB. The oscillations that occur approximately every 1.25 kHz are attributed to standing radial waves within the test section (1.25 kHz corresponds to the radius of the tunnel test section being a half wavelength). These oscillations are of the same order of magnitude as those found previously which indicates that lining the external water tank has resulted in an insignificant improvement.

The directivity function is usually presented in polar coordinates because the receiver is rotated about its axis during measurement. When the reflecting hydrophone is positioned next to the tunnel, however, only lateral translation up and down the test section is achievable. It is appropriate then to define an equivalent directivity function that uses the lateral location of the receiver relative to the projector as the independent variable. The projector was placed at the geometrical center of the test section, driven with a pure tone, and the received signal band-pass filtered at the frequency of the tone. Using the traversing mechanism, the receiver scanned the sound field from 60 inches upstream

to 60 inches downstream of the projector. The traversing mechanism is calibrated from 0 to 120 inches with 0 representing the downstream extremum. With this lateral coordinate convention, x=60 inches corresponds to the center of the test section.

Figures 20 through 27 show the results of these scans for eight discrete frequencies. It is seen that for all frequencies considered, a minima occurs near the location of the ribs dividing the three windows, i.e., x=43 inches and x=77 inches which indicates acoustic blockage. Because of reflections in the test section, the directivity characteristics are somewhat impared as compared to Figures 11 through 18 for the free field. Nevertheless, most side lobes are at least 6 or more dB below the on axis level, particularly for frequencies greater than 30 kHz.

CONCLUSIONS

The Applied Research Laboratory/Fluids Engineering Unit has been involved with the measurement of radiated sound from hydrodynamic models operating in the 48-inch diameter water tunnel using an ellipsoidal reflecting hydrophone. Modifications were made to this system for the purpose of enhancing its acoustic performance. These modifications included: (1) the lining of the concave surface of the reflector with highly reflective bubble rubber; (2) the replacement of the ARL home-built hydrophone probe (located at focus of reflector) with a commercially-made, Celesco Corp. LC-10 probe; and (3) the lining of the external tank that houses the system with Saper T, a sound absorbing rubber. The modifications were evaluated by comparing directivity and sensitivity characteristics before and after the modification in both the water tunnel and free field. From these evaluations it can be concluded that: (1) the coating of the reflector with bubble rubber has increased the system's sensitivity by 6 to 8 dB depending on the frequency: (2) the LC-10 hydrophone probe placed at the focus of the reflector results in a flatter free-field response; and (3) the lining of the external tank with sound absorbing rubber did not alter the standing wave character of the in-tunnel sensitivity response curve.

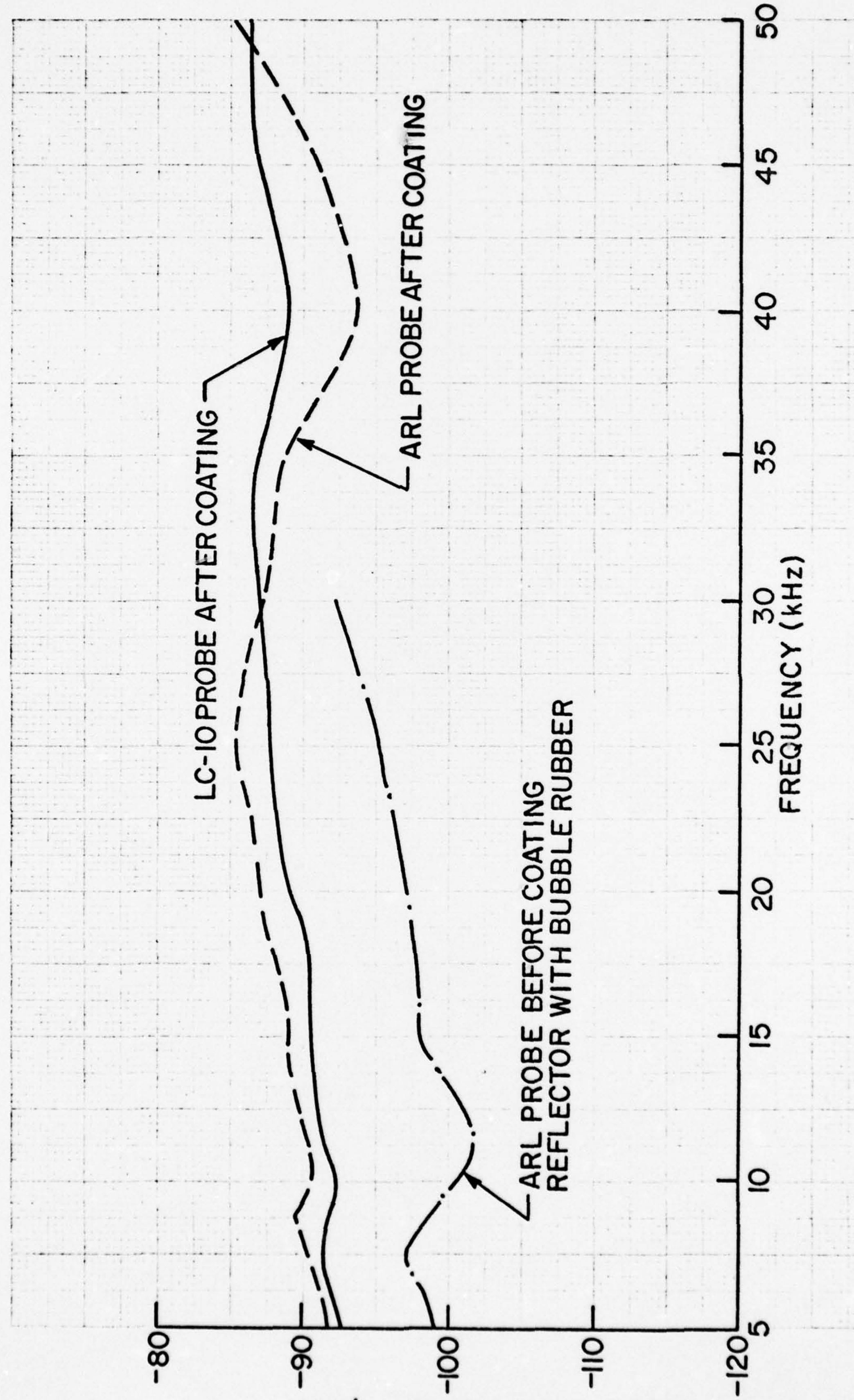

Figure 1 - Free-Field Sensitivities

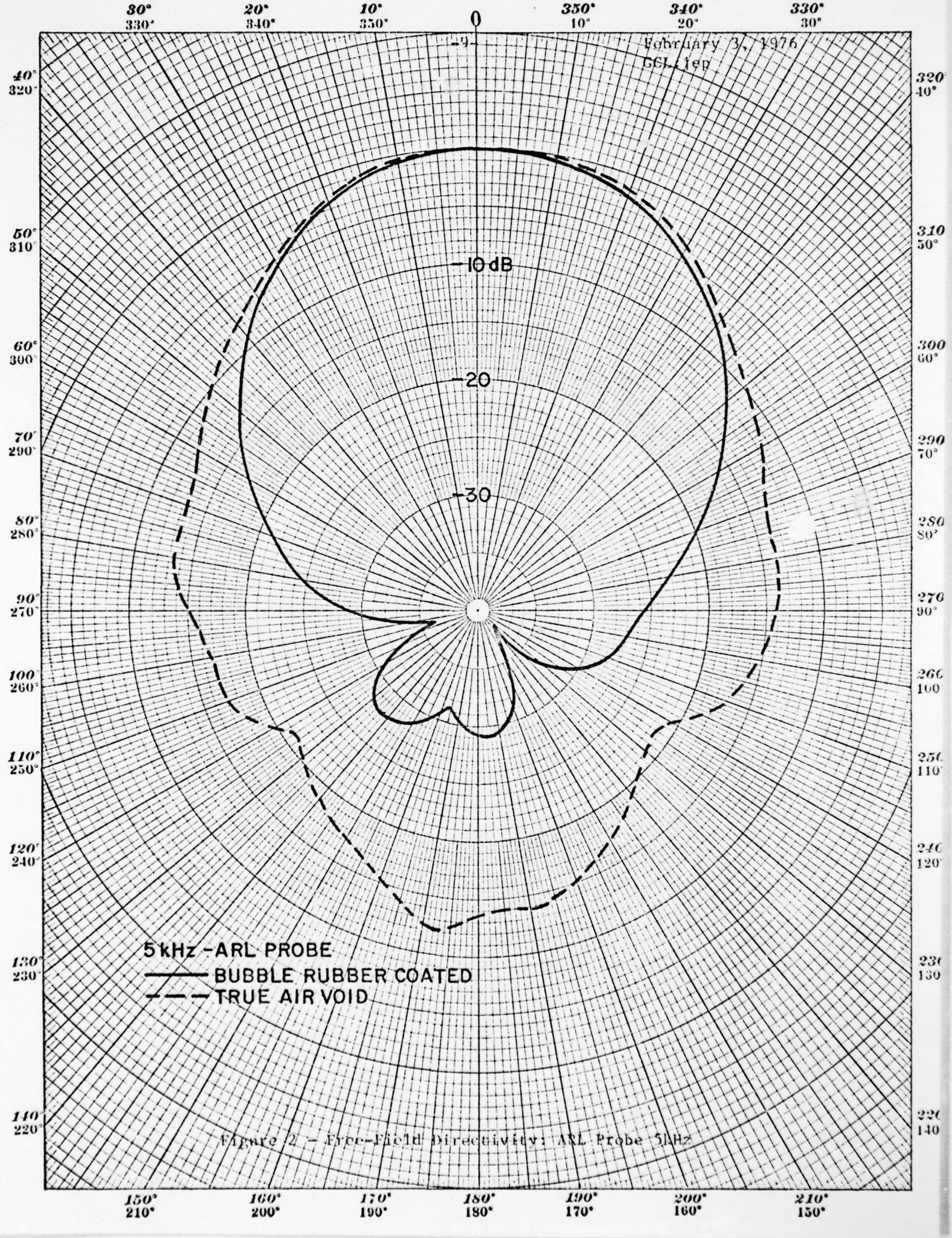

Figure 2 - Free-Field Directivity: ARL Probe 5kHz

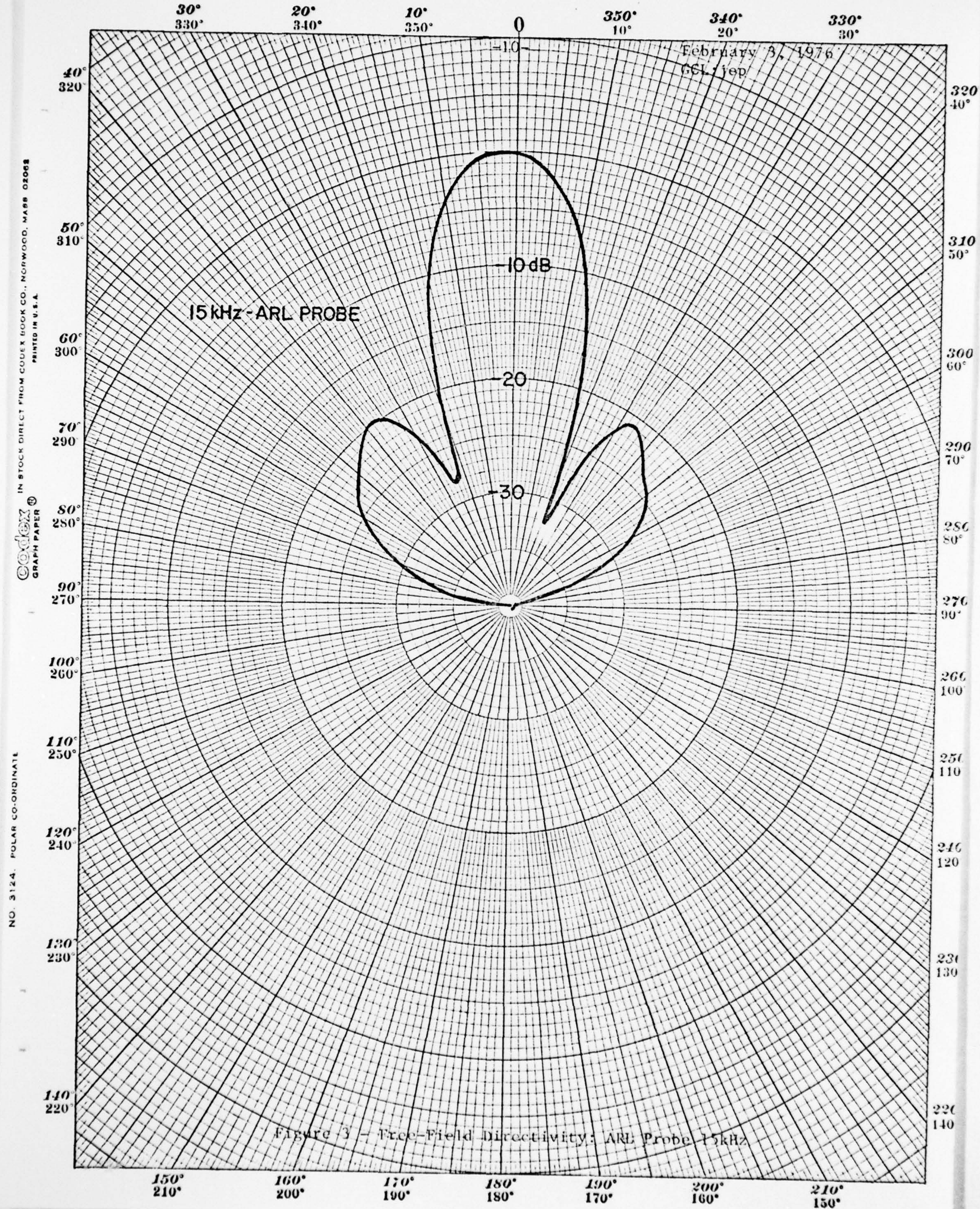

Figure 3 - Free-Field Directivity; ARL Probe 15kHz

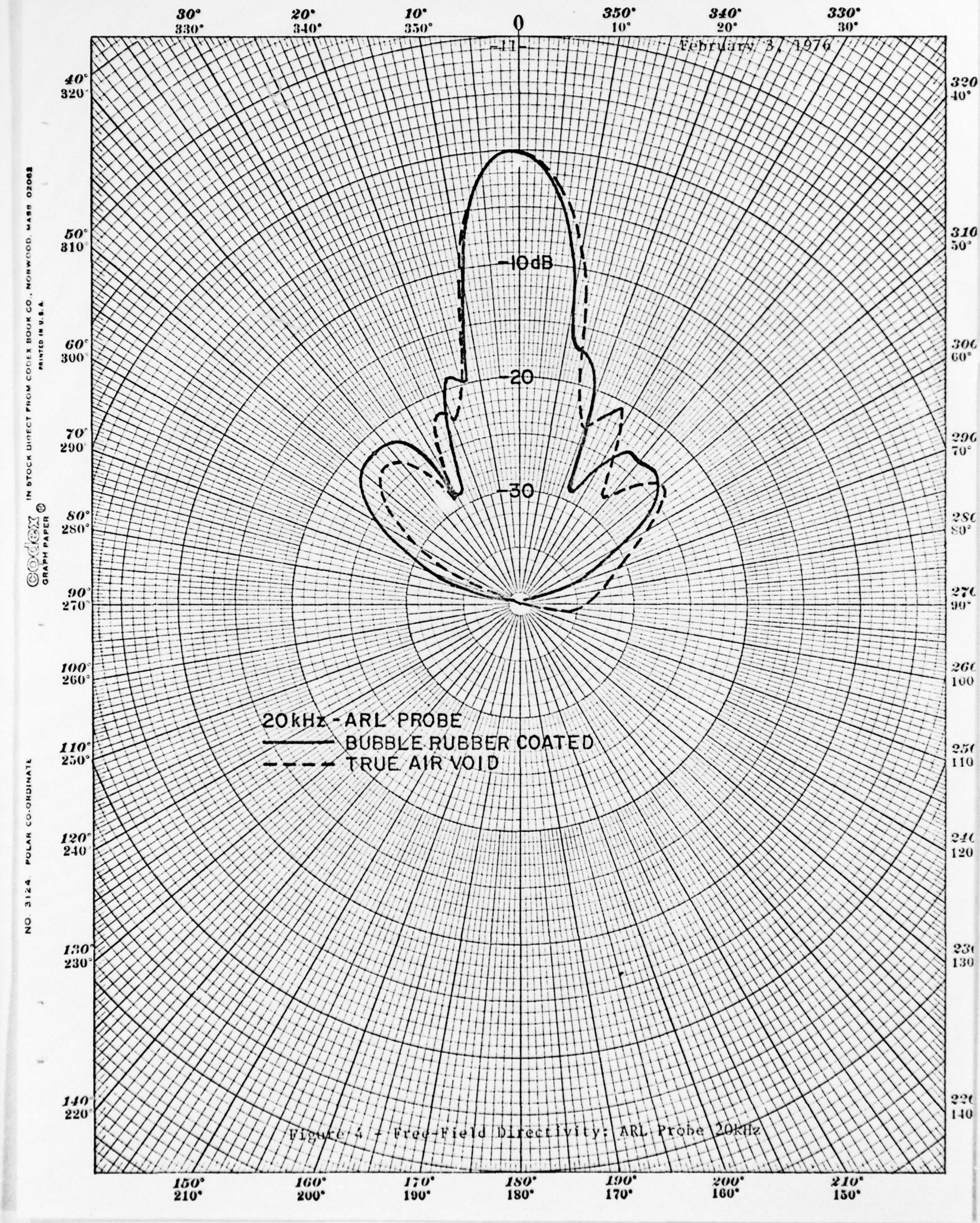

Figure 4 - Free-Field Directivity: ARL Probe 20kHz

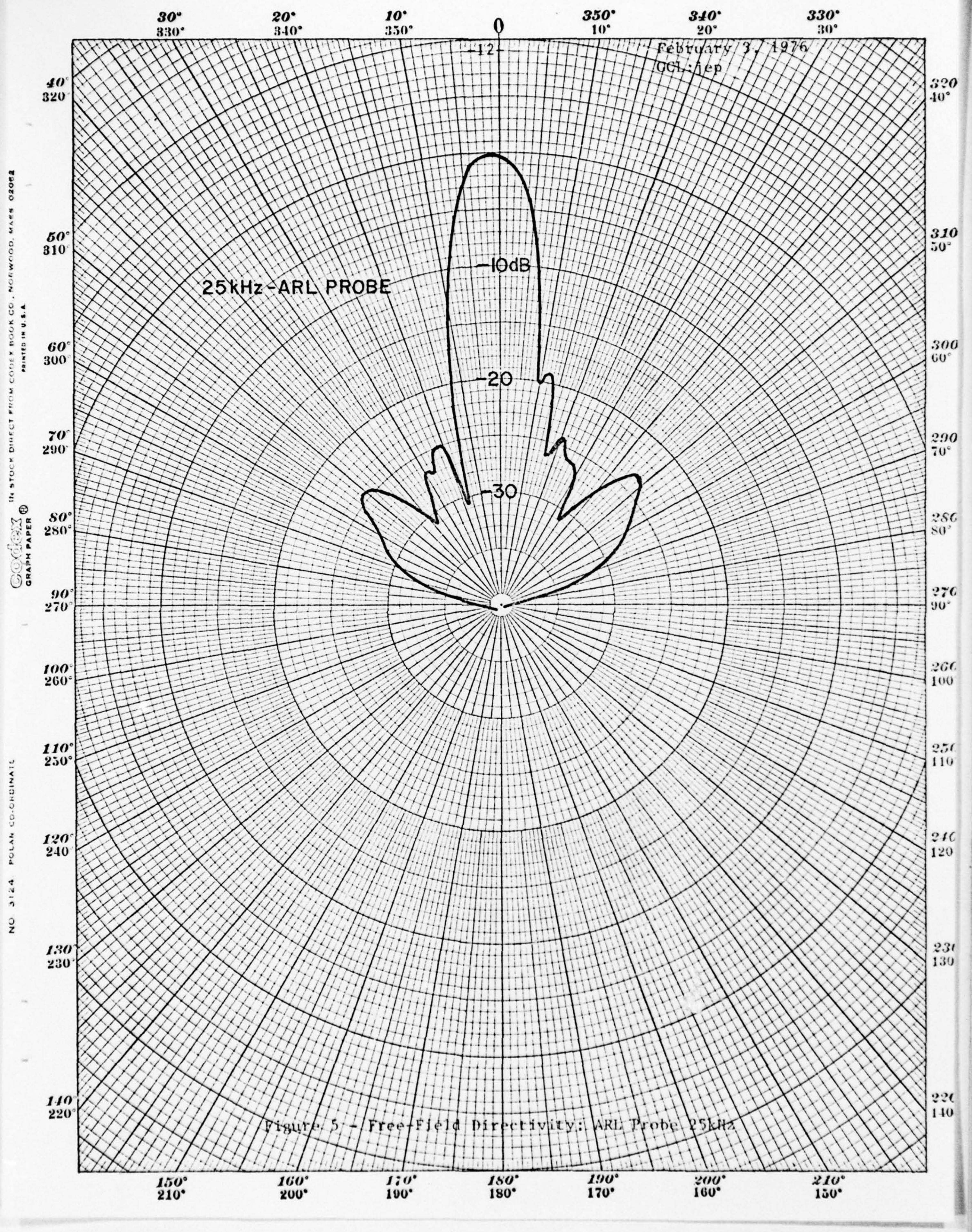

Figure 5 - Free-Field Directivity: ARL Probe 25kHz

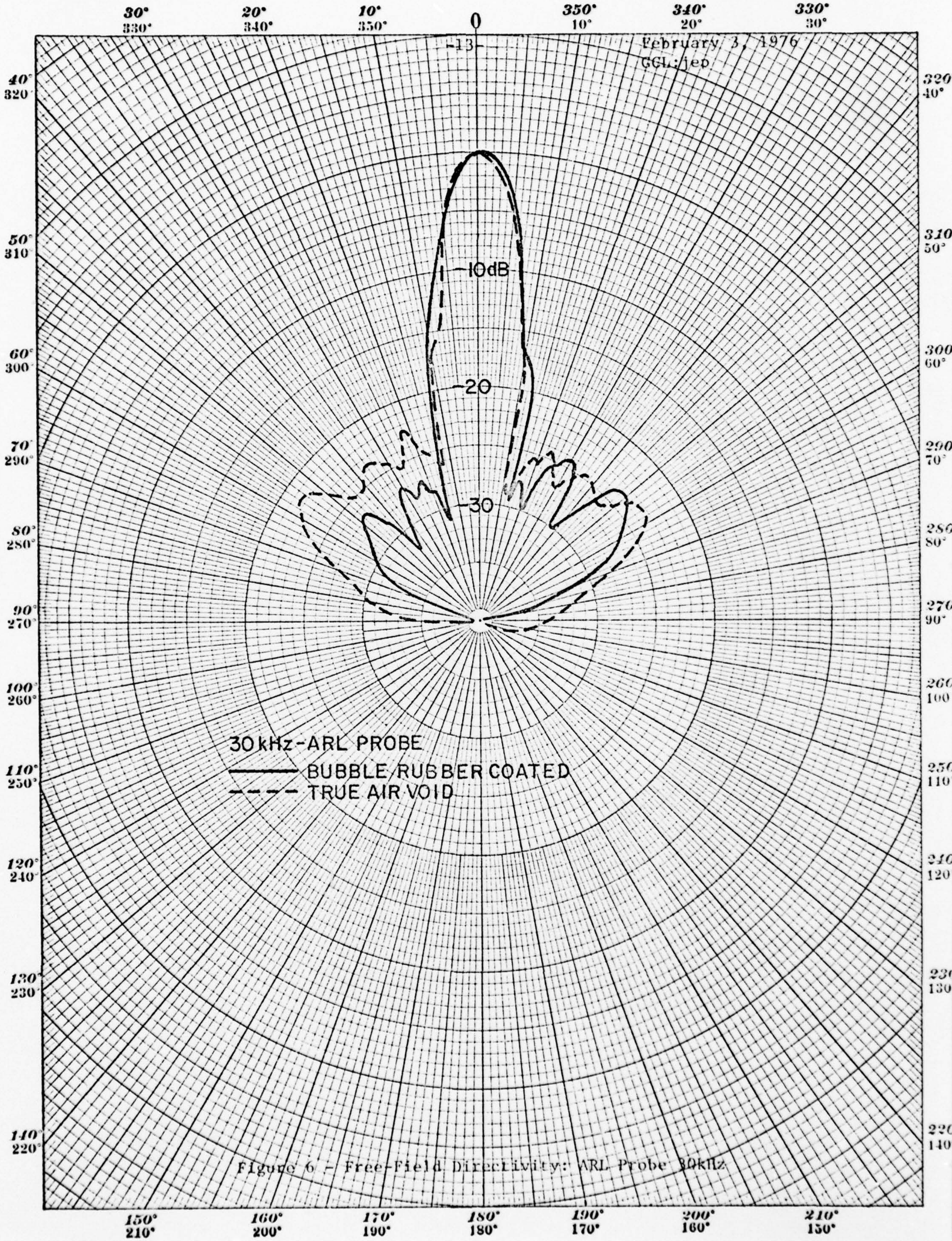

Figure 6 - Free-Field Directivity: ARL Probe 30kHz

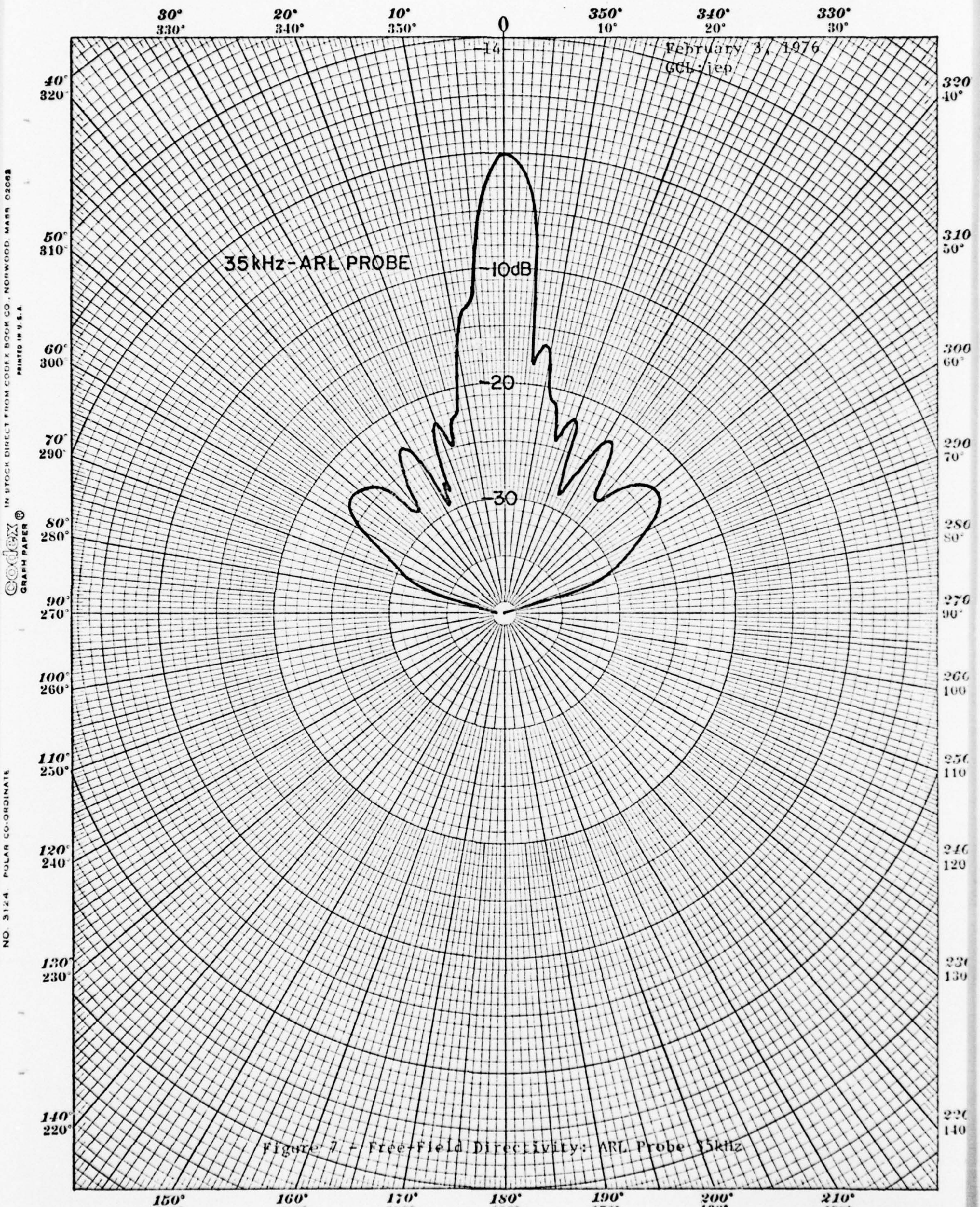

Figure 7 - Free-Field Directivity: ARL Probe 35kHz

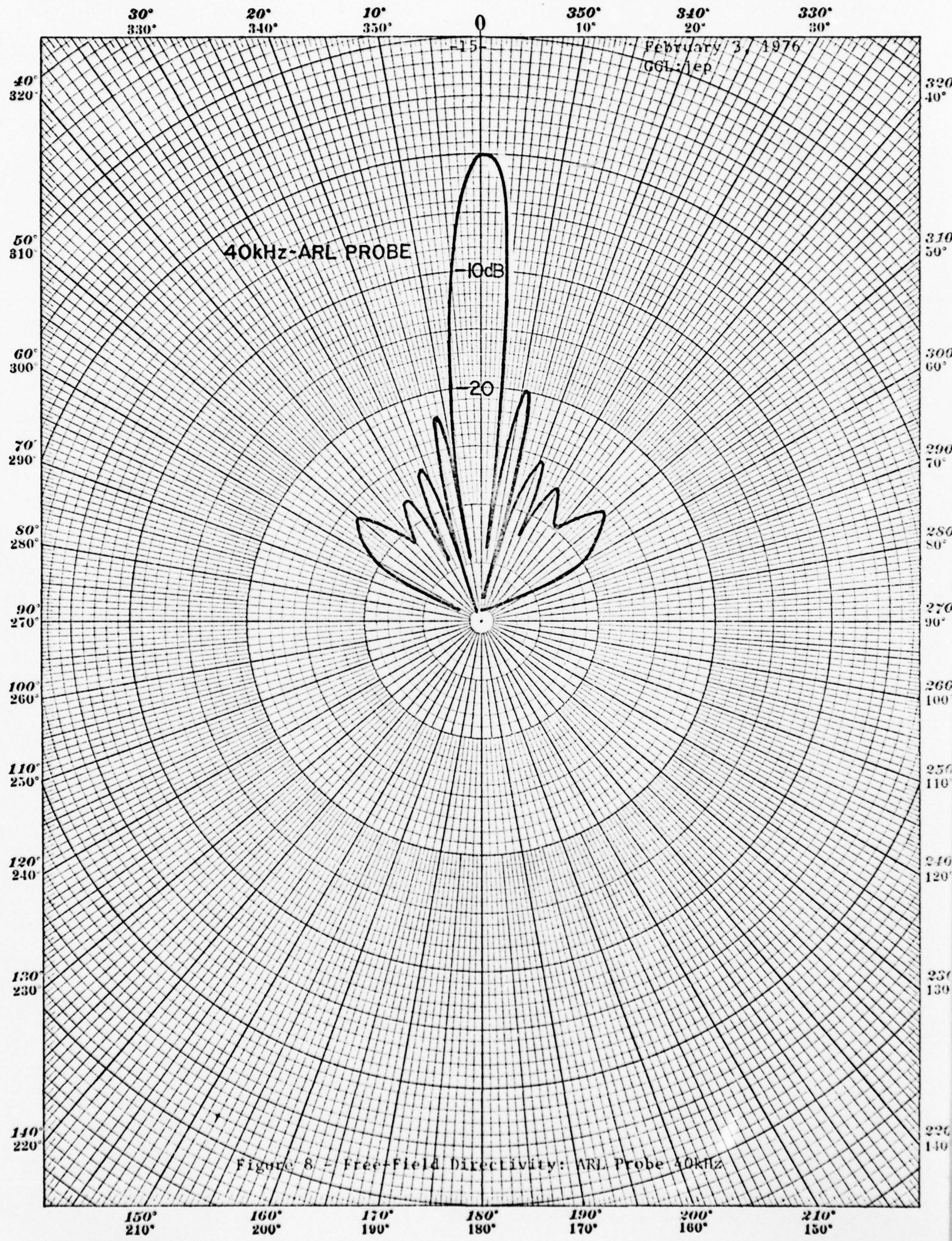

Figure 8 - Free-Field Directivity: ARL Probe 40kHz

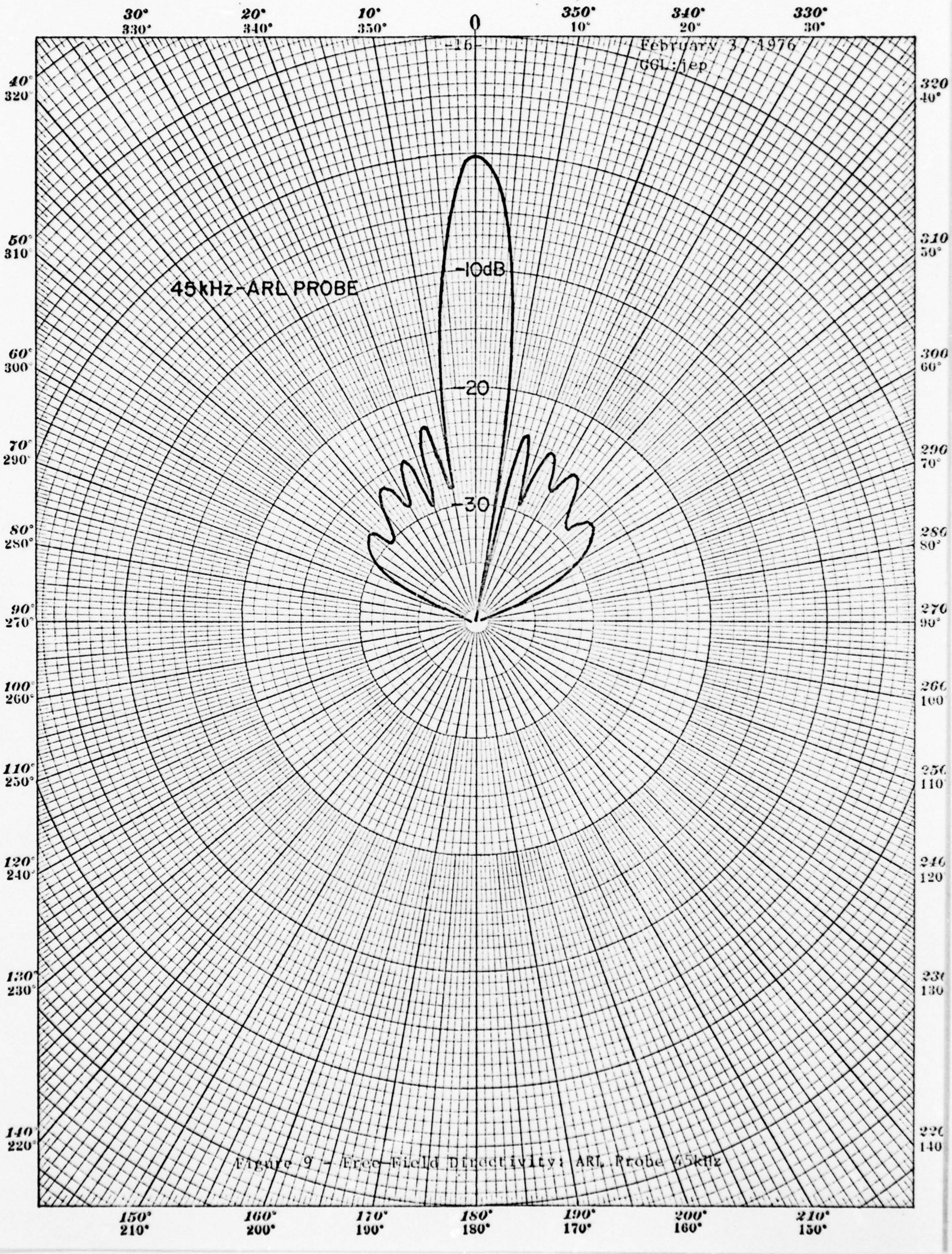

Figure 9 - Free-Field Directivity: ARL Probe 45kHz

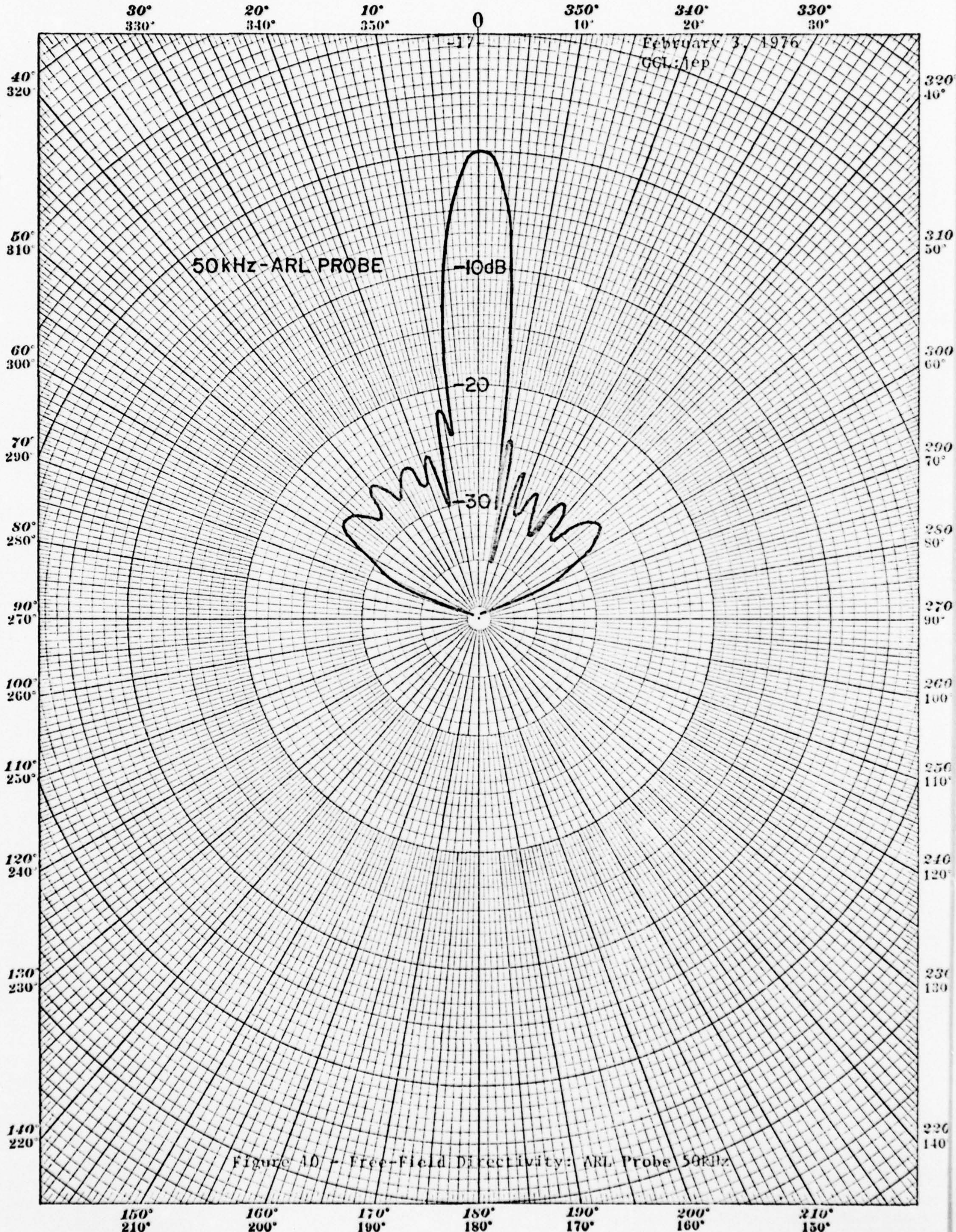

Figure 10 - Free-Field Directivity: ARL Probe 50kHz

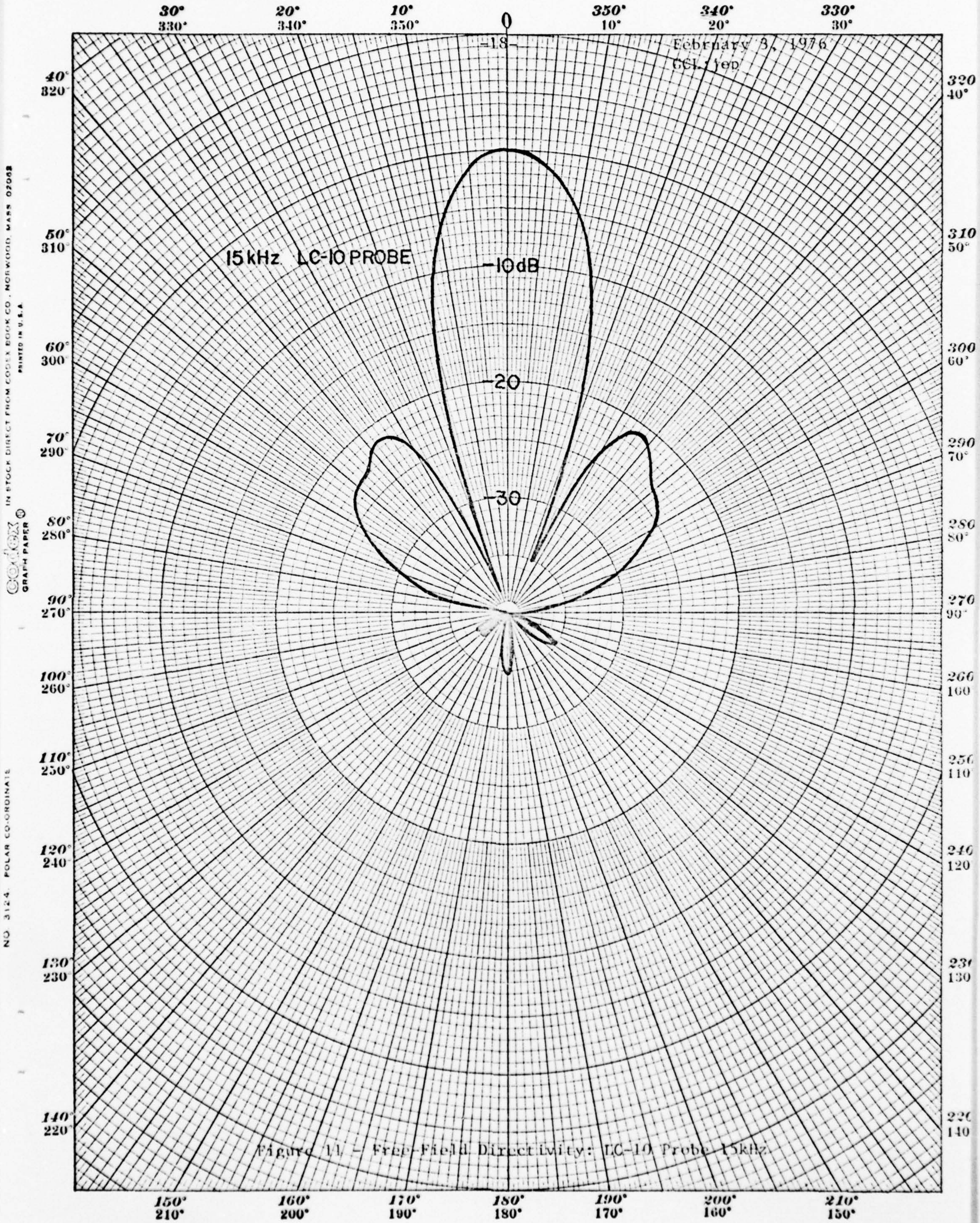

Figure 11 - Free-Field Directivity: LC-10 Probe 15kHz

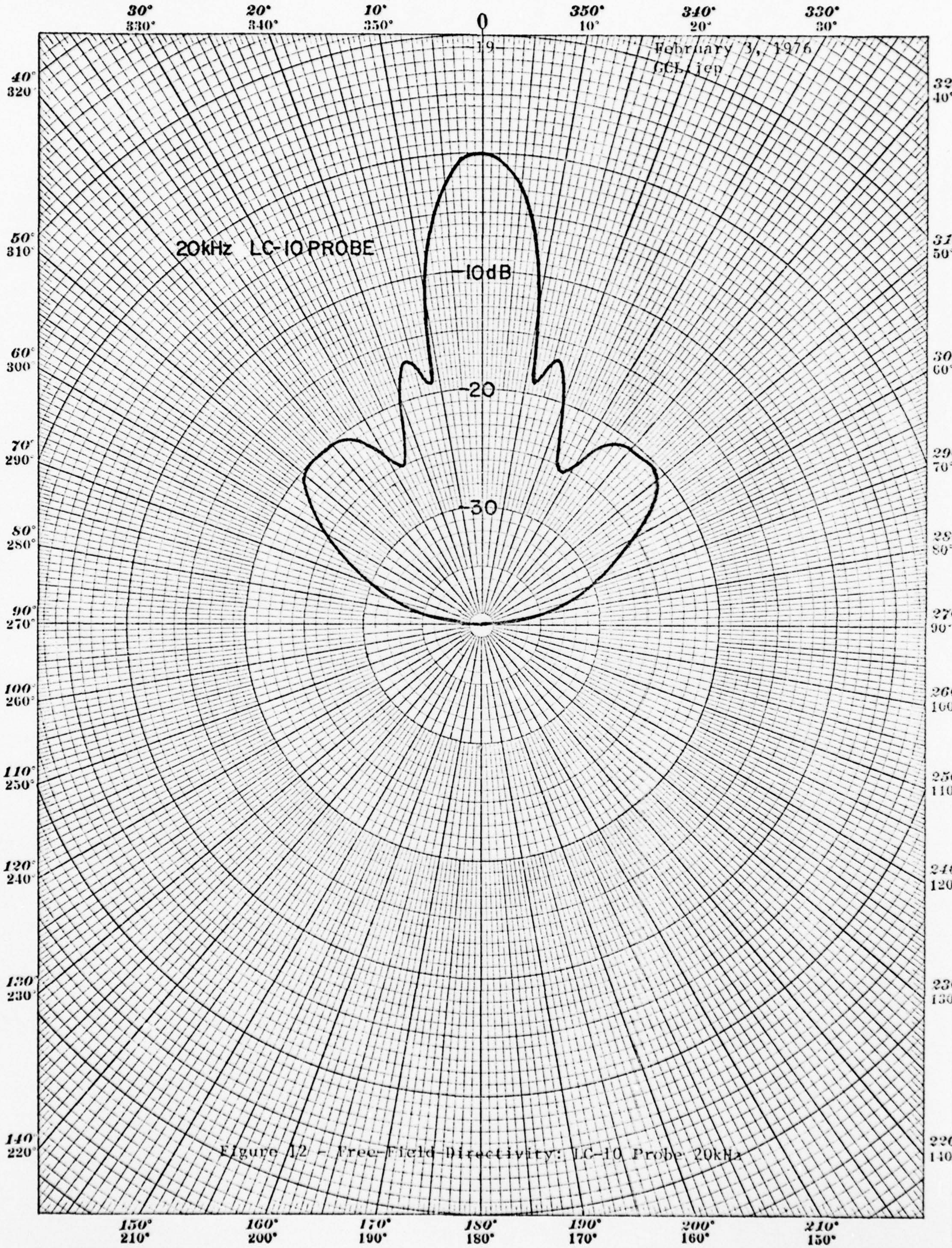

Figure 12 - Free-Field Directivity: LC-10 Probe 20kHz

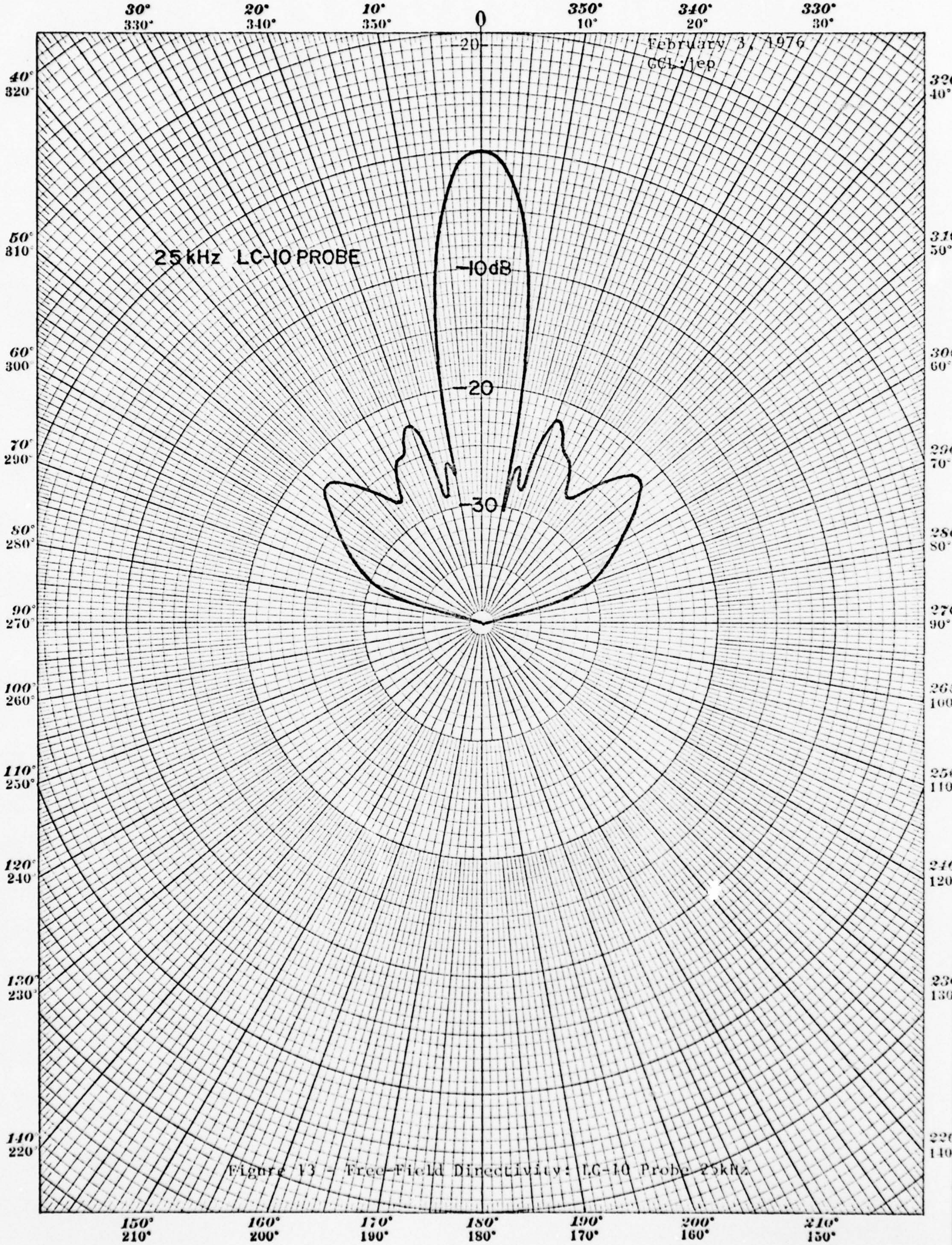

Figure 13 - Free-Field Directivity: LC-10 Probe 25kHz

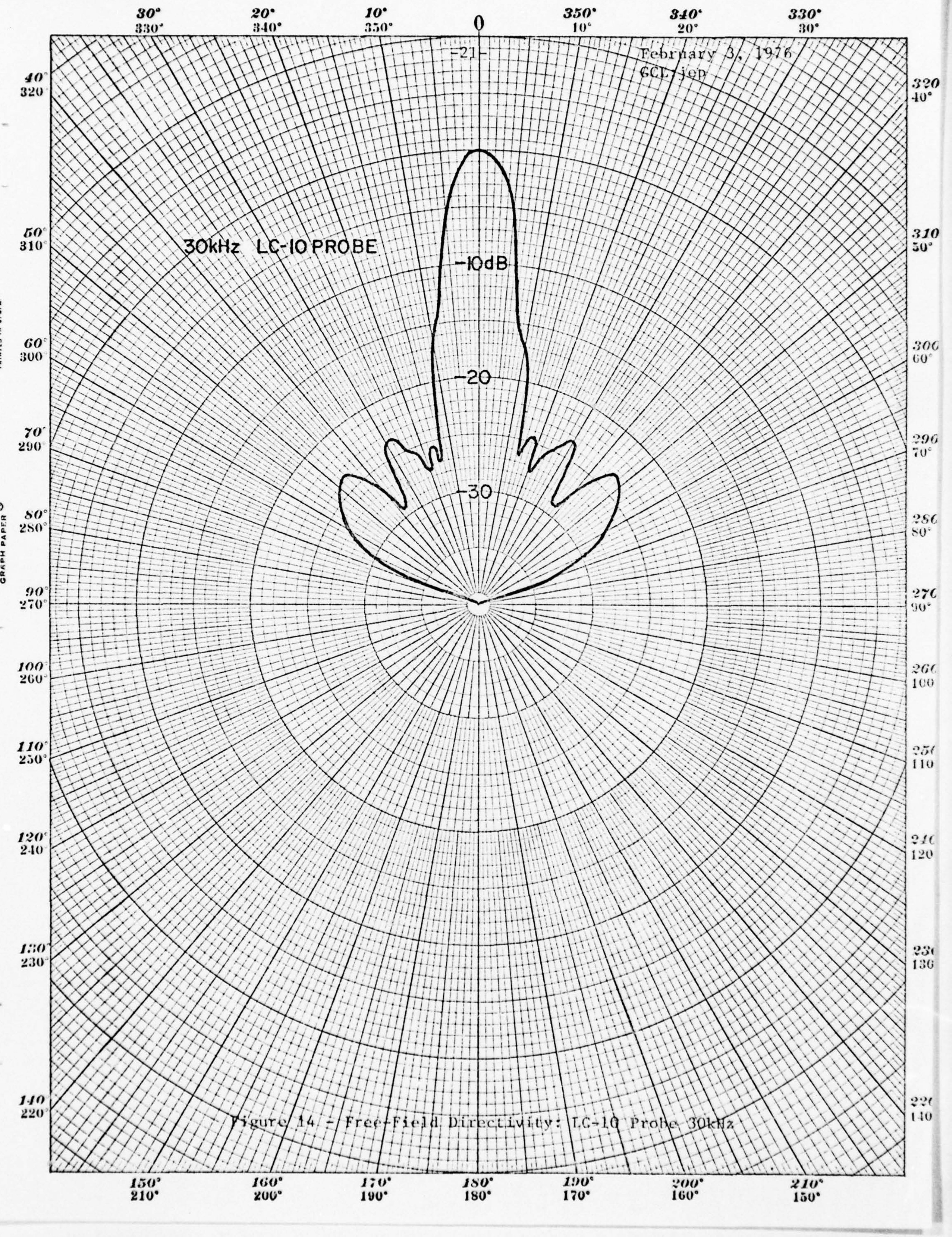

Figure 14 - Free-Field Directivity: LC-10 Probe 30kHz

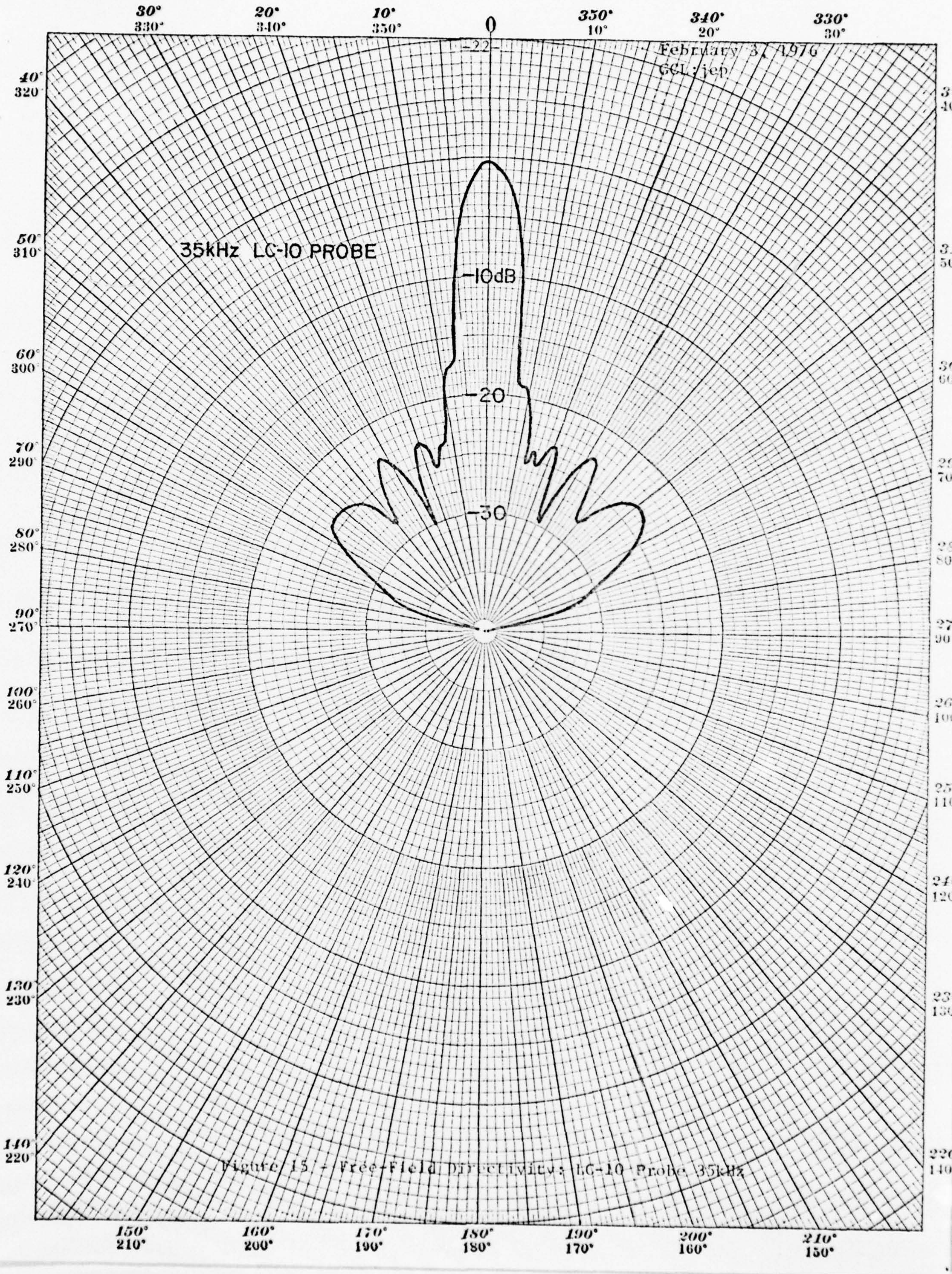

Figure 15 - Free-Field Directivity; LC-10 Probe 35kHz

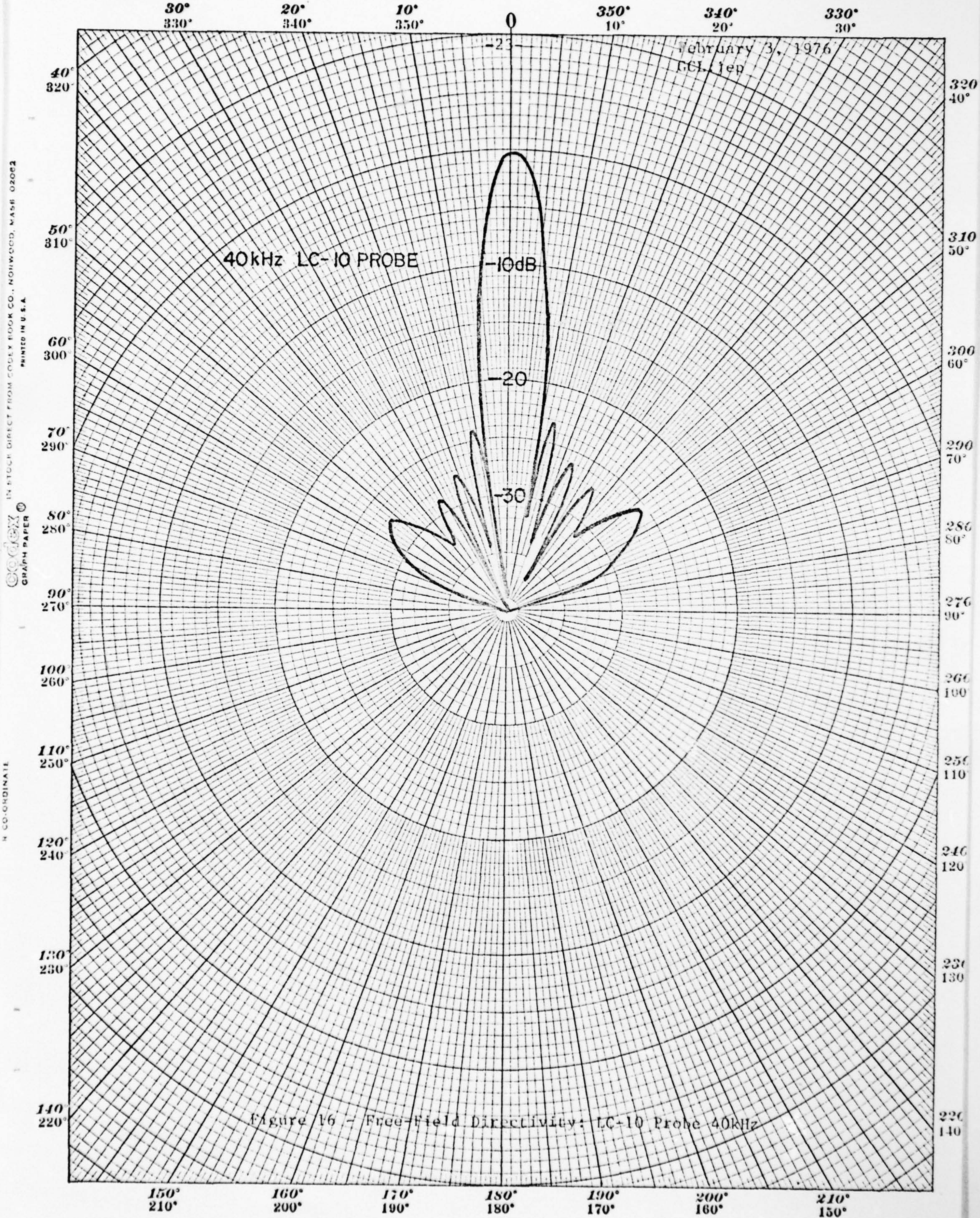

Figure 16 - Free-Field Directivity: LC-10 Probe 40kHz

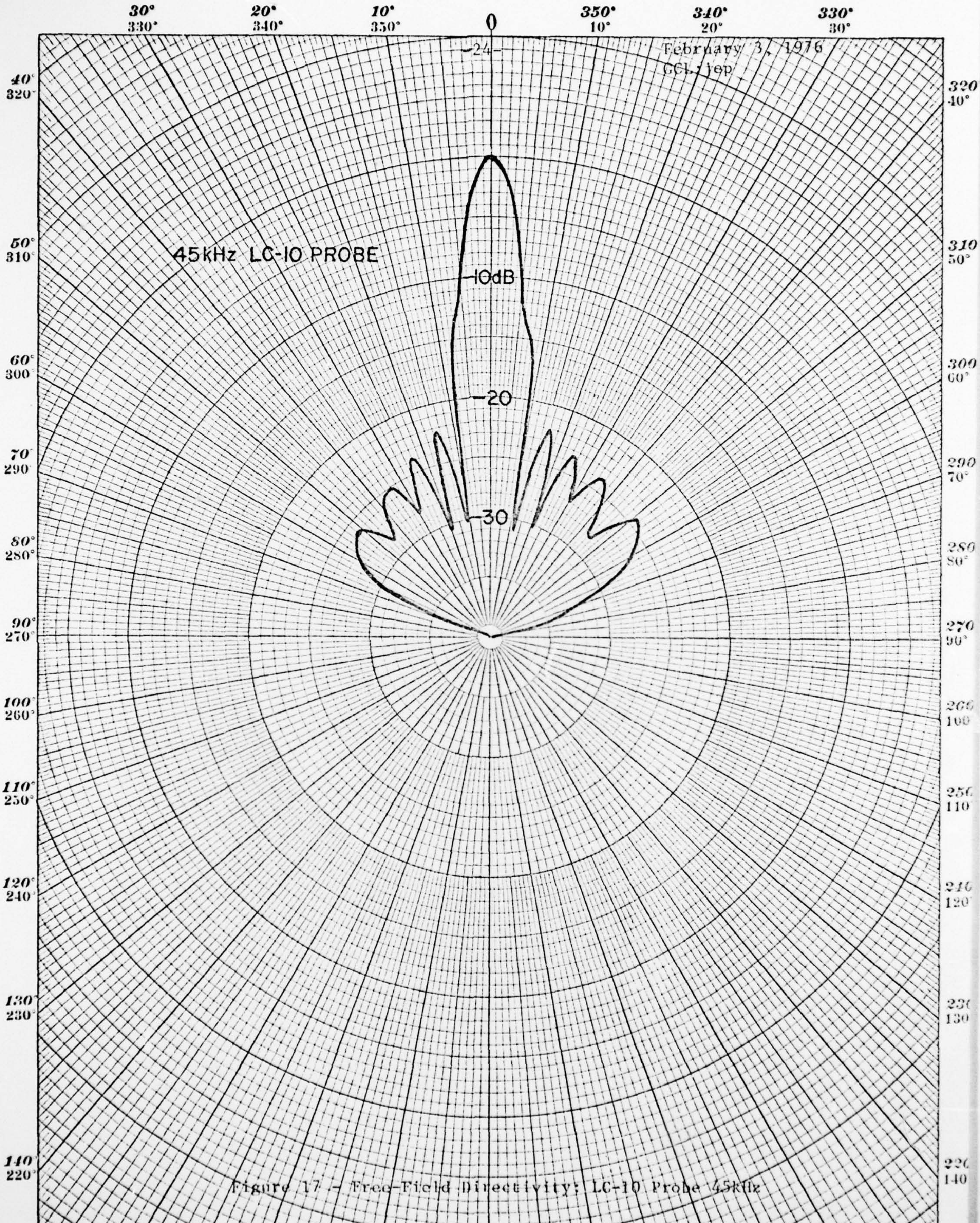

Figure 17 - Free-Field Directivity: LC-10 Probe 45kHz

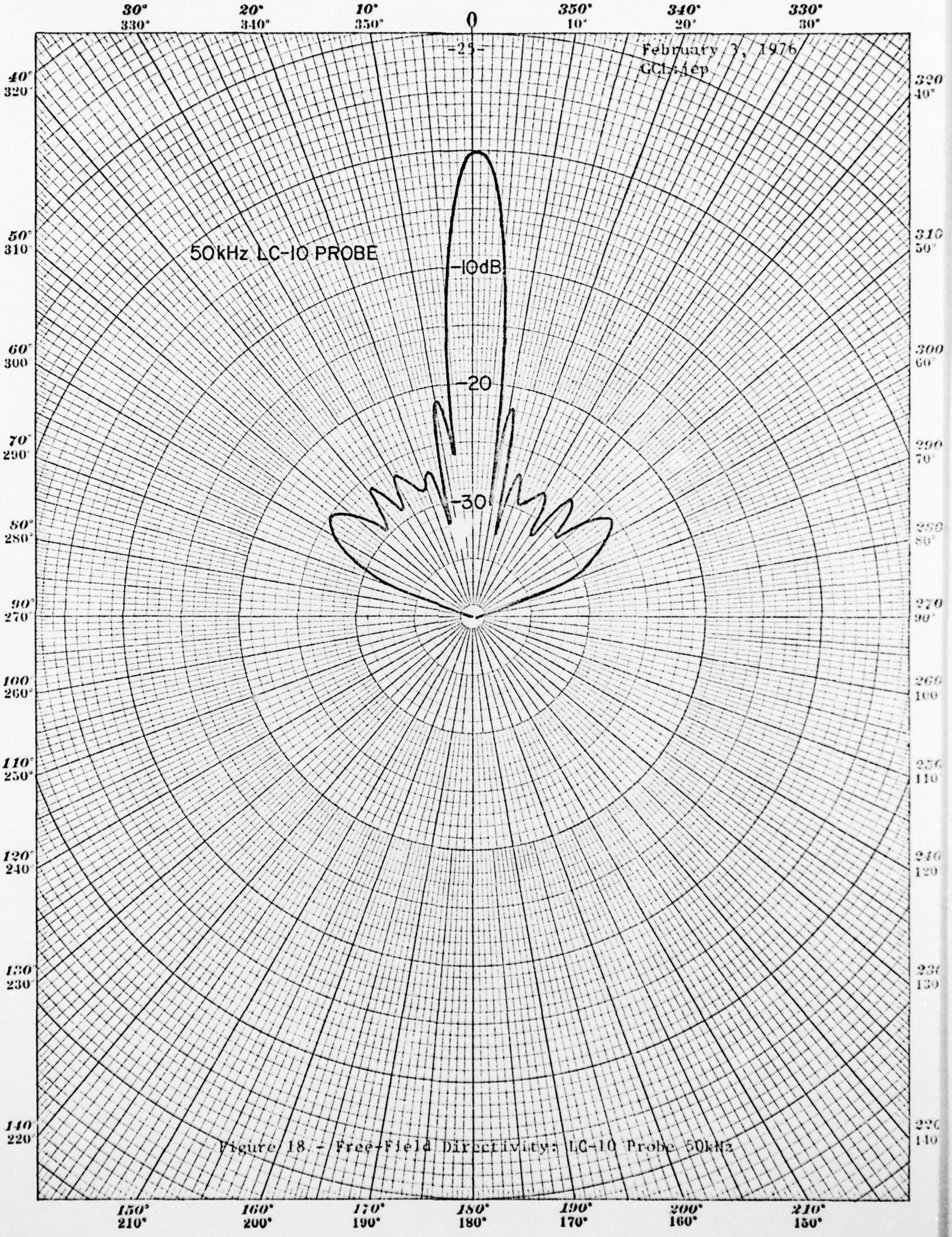

Figure 18. - Free-Field Directivity: LC-10 Probe 50kHz

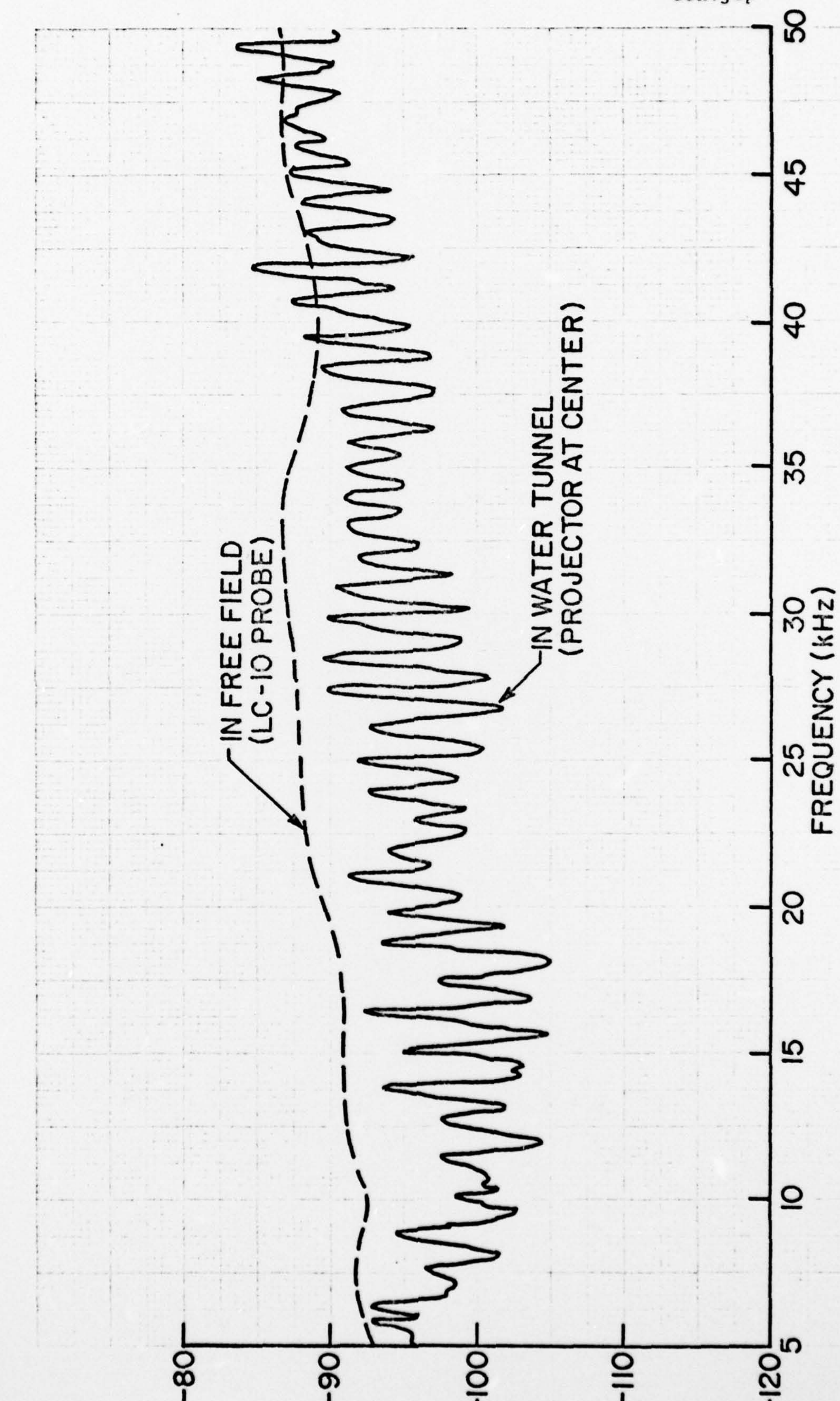

Figure 19 - Sensitivity in Water Tunnel

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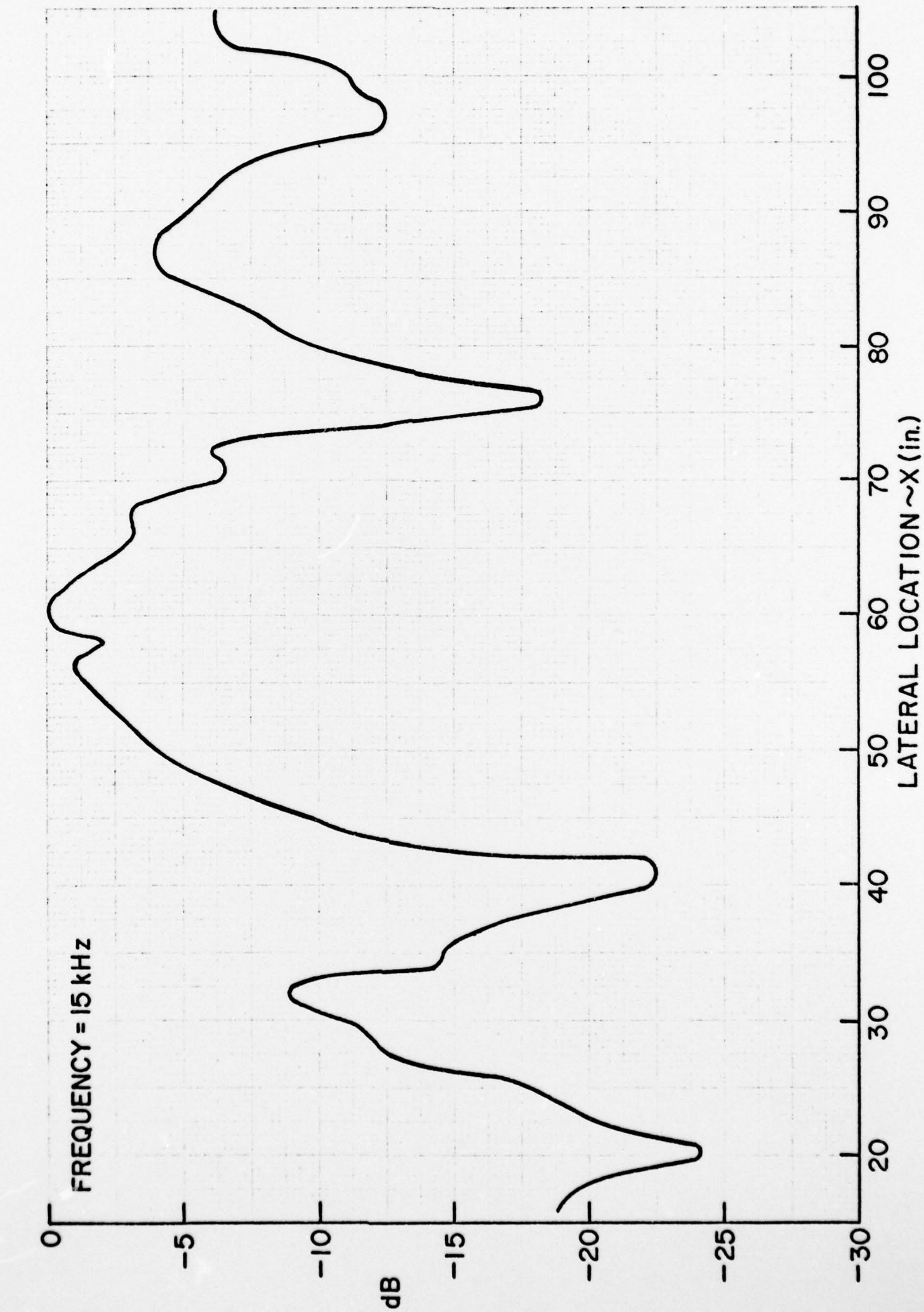

Figure 20 - Directivity in Water Tunnel: LC-10 Probe 15kHz

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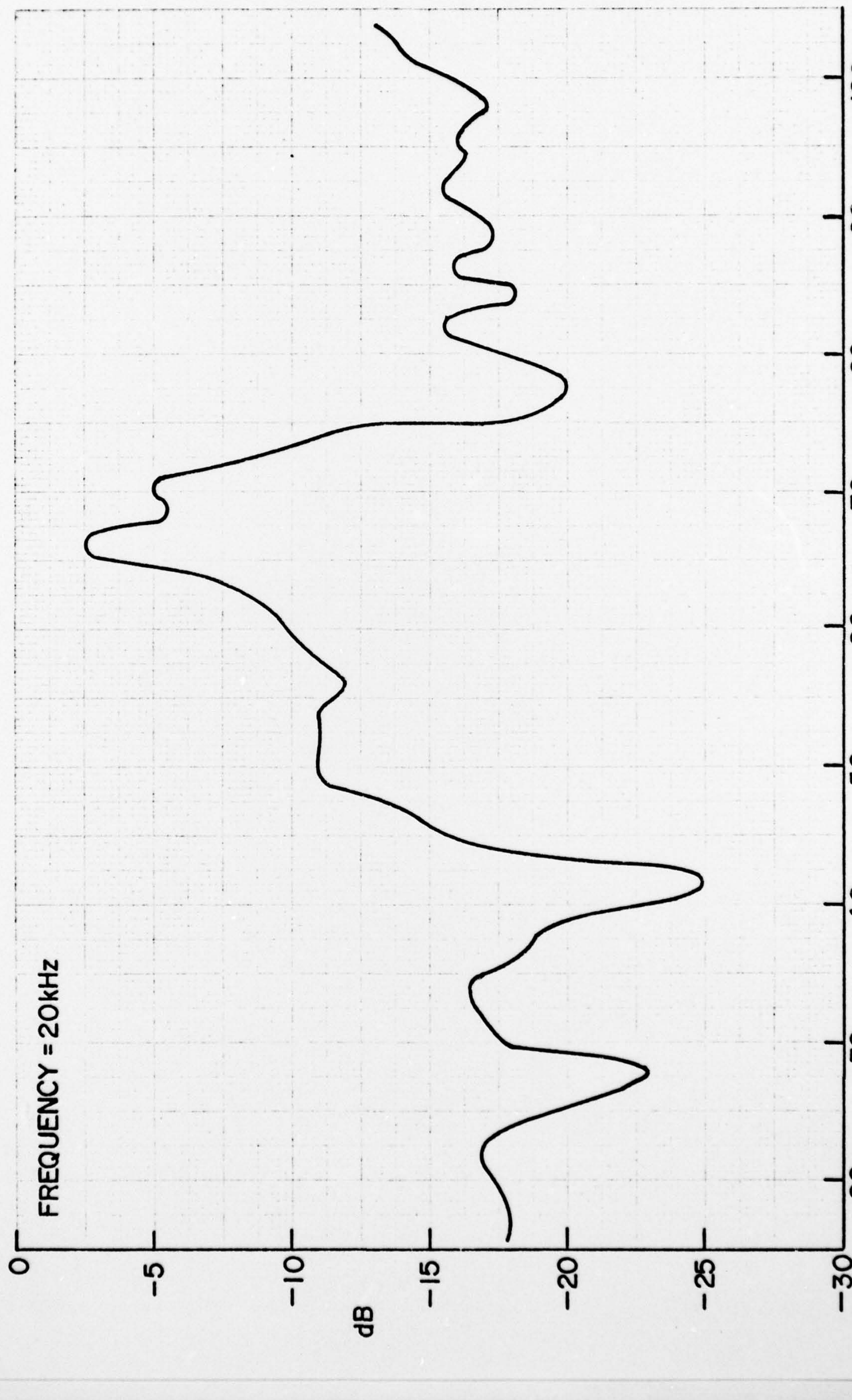

Figure 21 - Directivity in Water Tunnel: LC-10 Probe 20kHz

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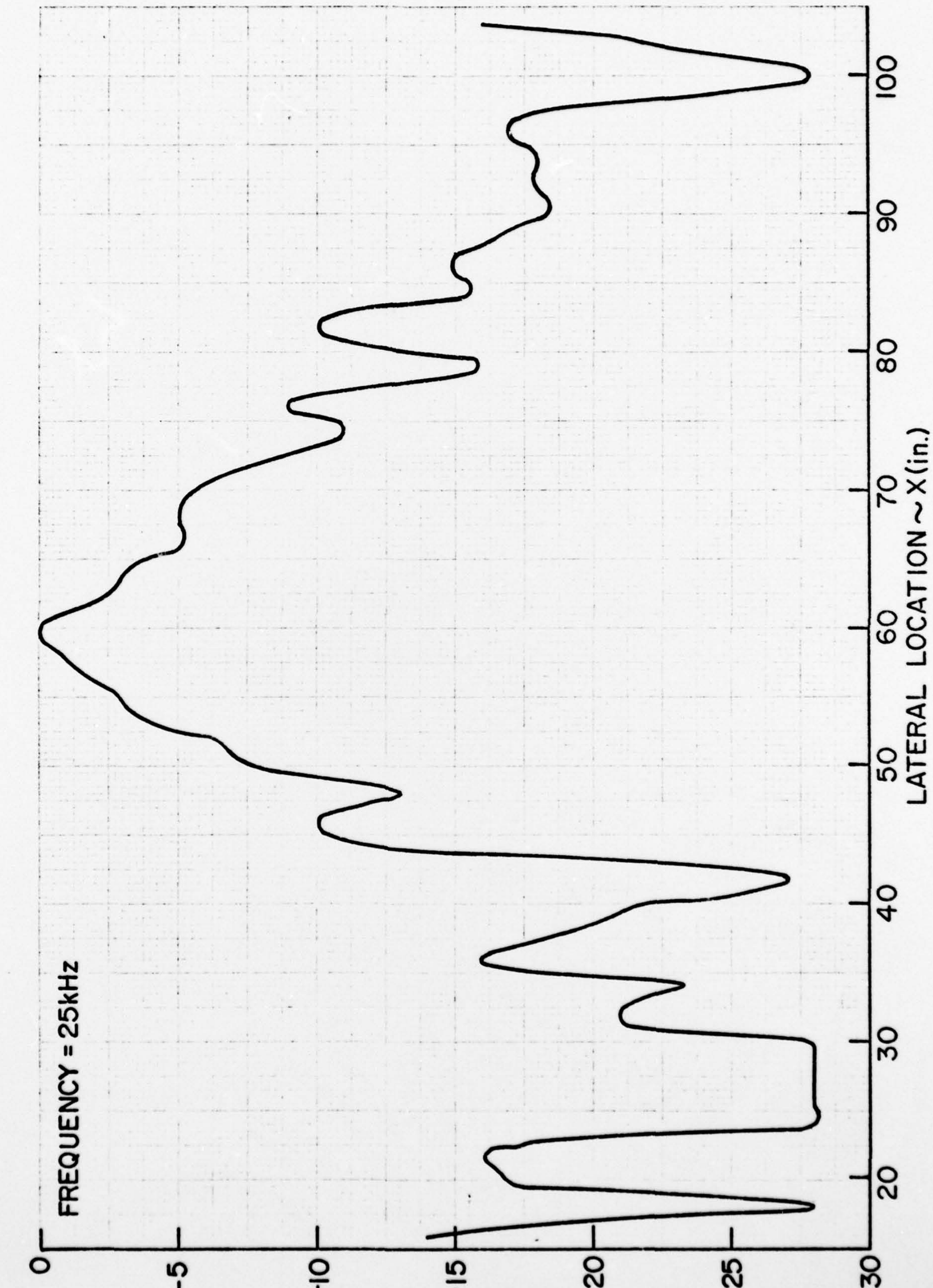

Figure 22 - Directivity in Water Tunnel: LC-10 Probe 25kHz

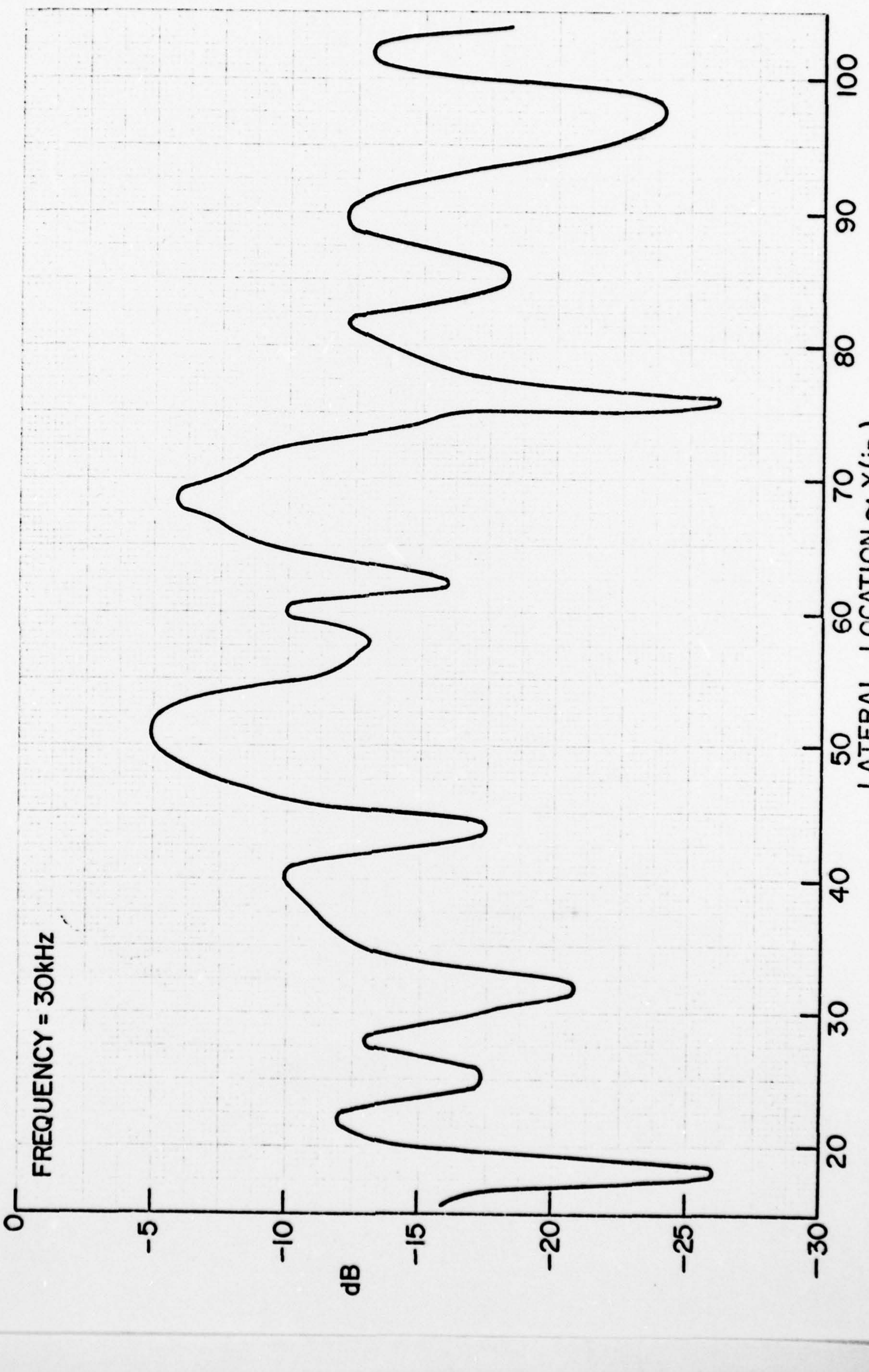

Figure 23 - Directivity in Water Tunnel: LC-10 Probe 30kHz

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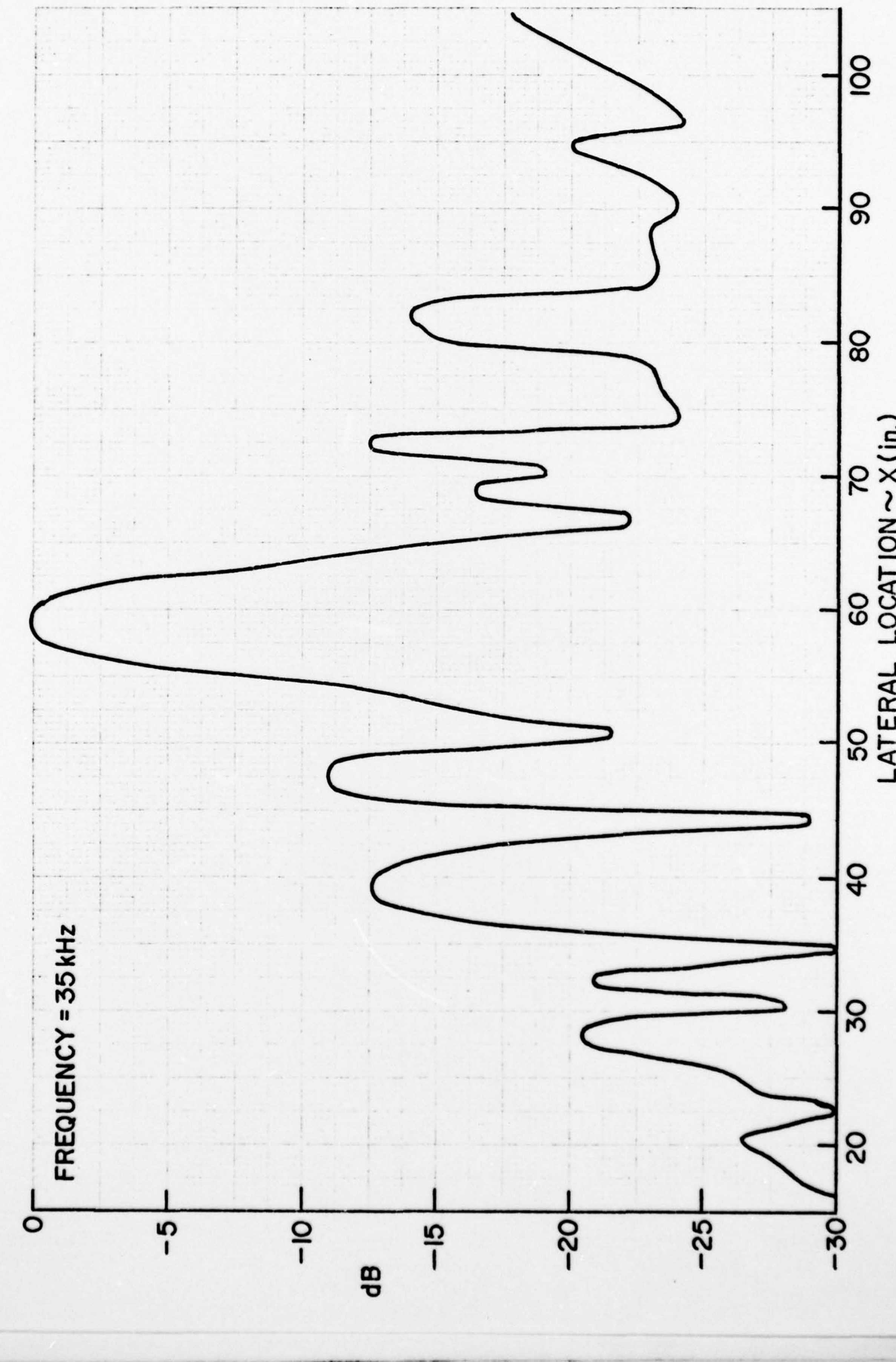

Figure 24 - Directivity in Water Tunnel: LC-10 Probe 35kHz

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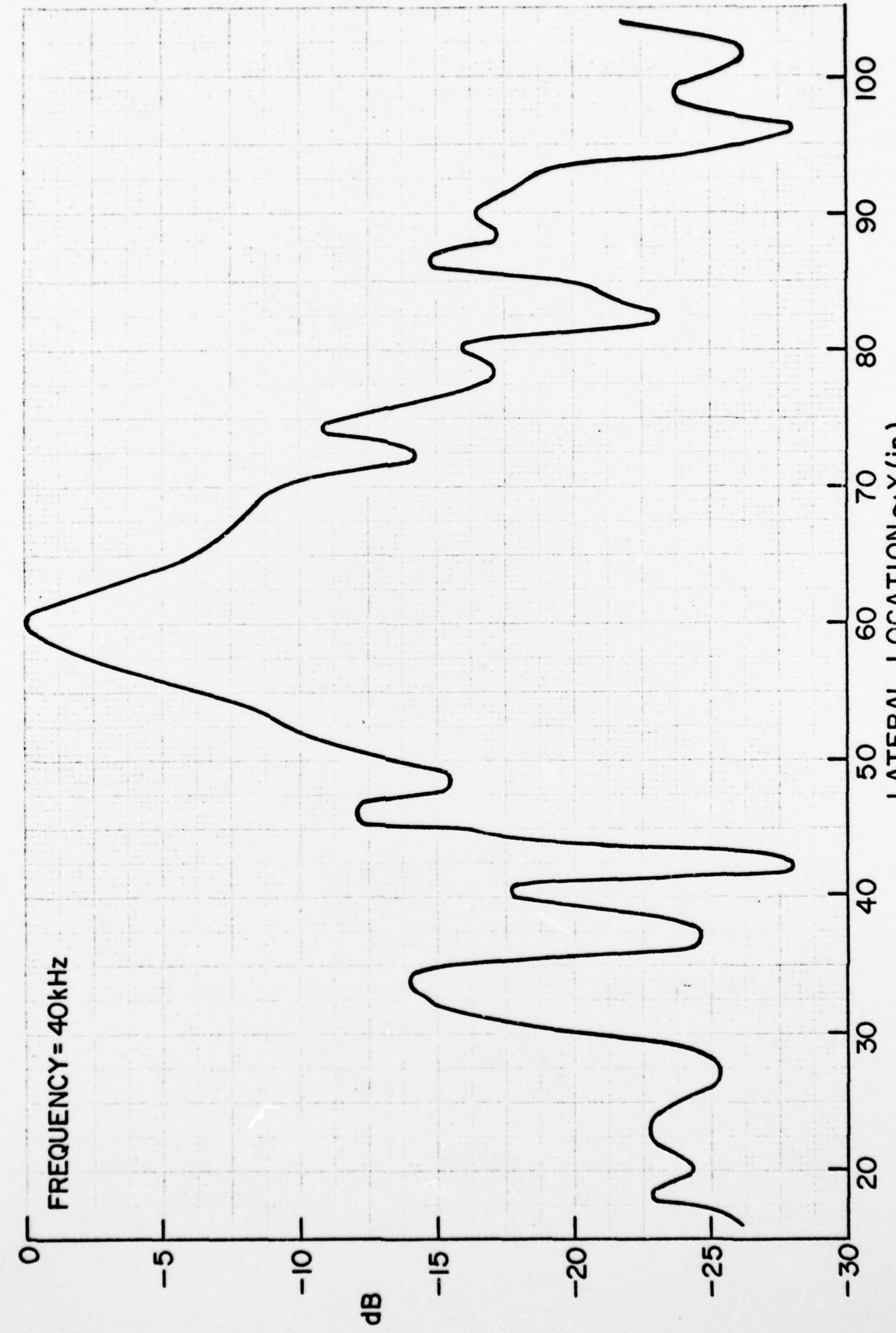

Figure 25 - Directivity in Water Tunnel: LC-10 Probe 40kHz

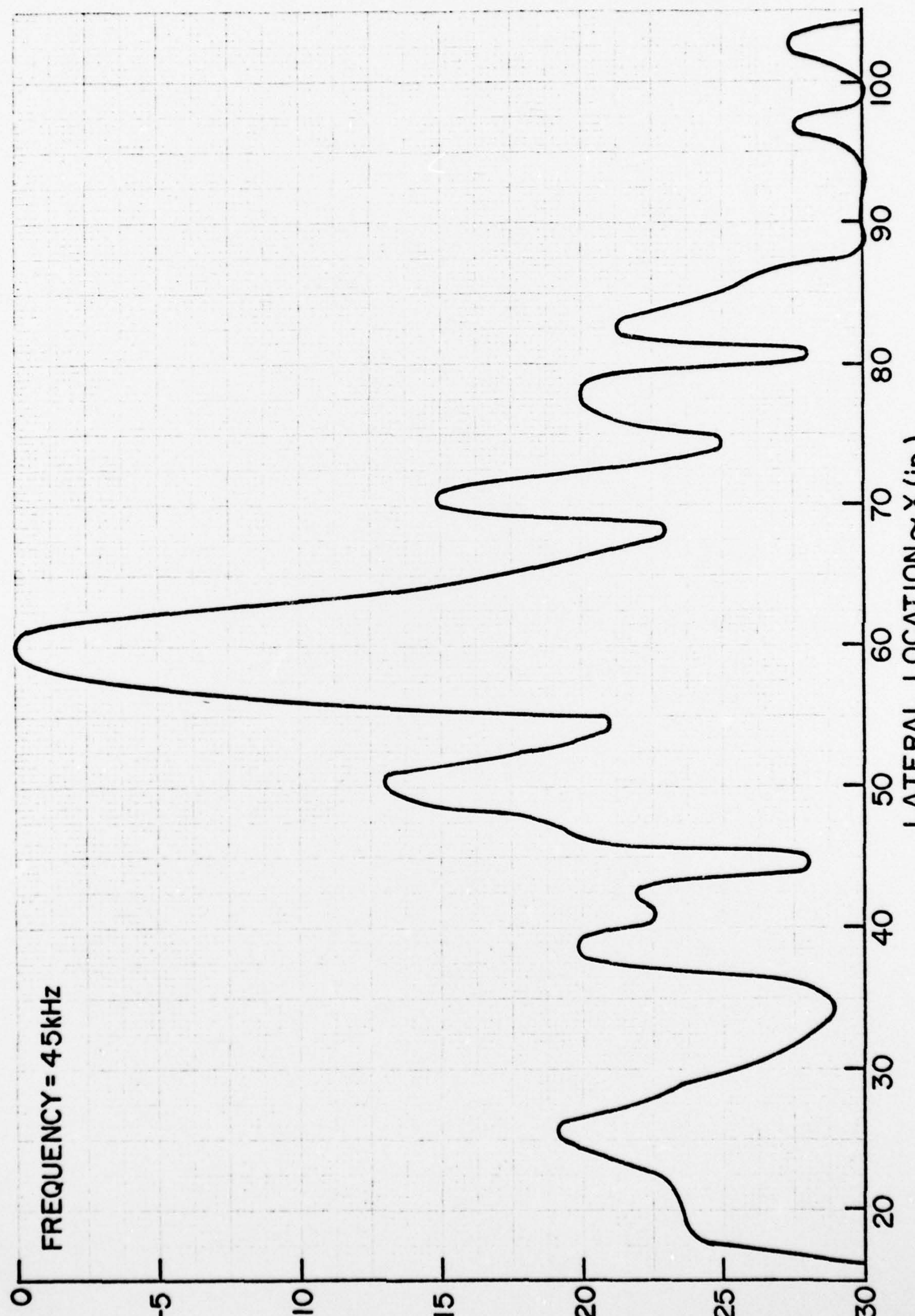

Figure 26 - Directivity in Water Tunnel: LC-10 Probe 45kHz

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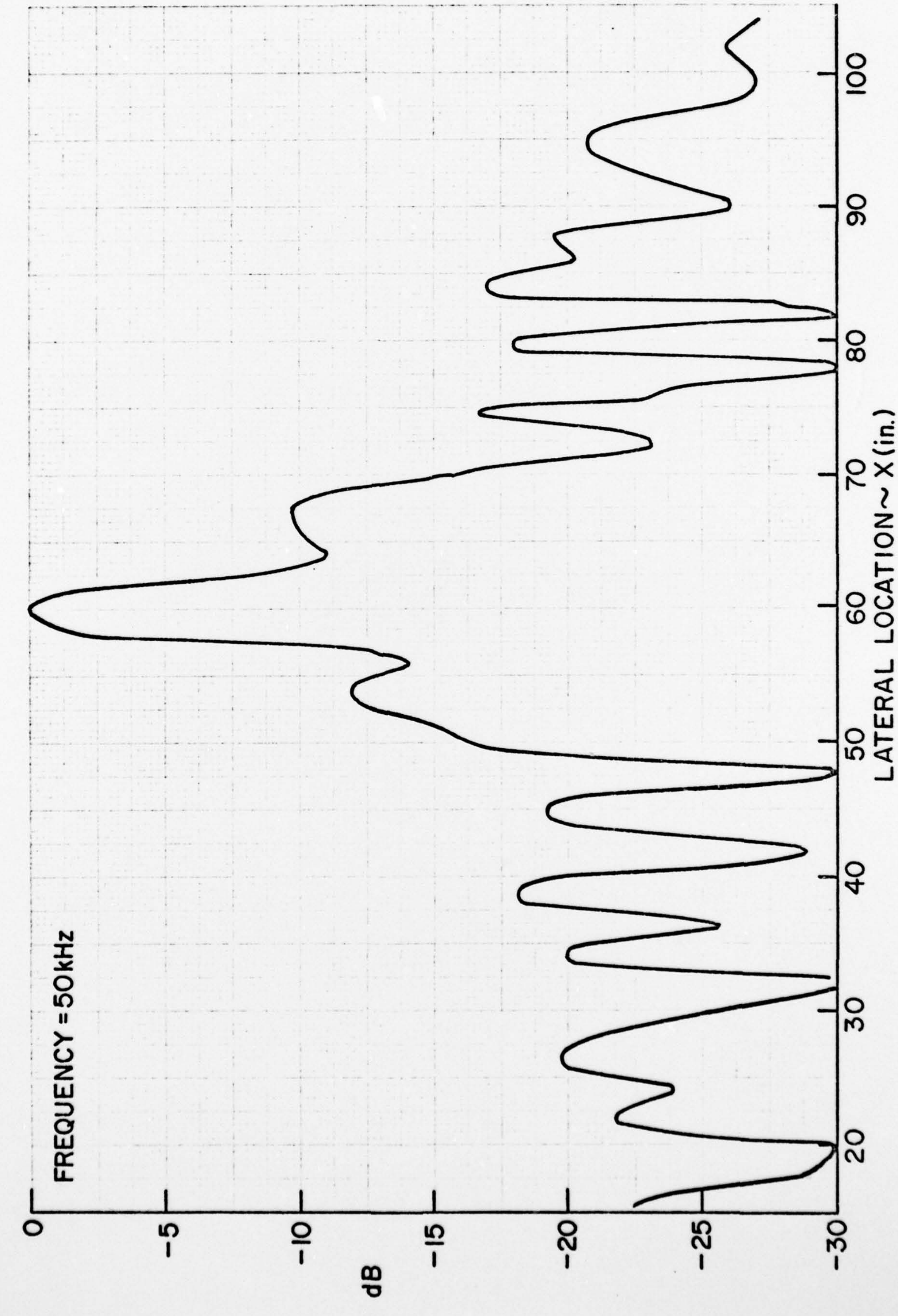

Figure 27 - Directivity in Water Tunnel: LC-10 Probe 50kHz

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